JOYCE
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SCIENTIFIC DIALOGUES.

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

Natural and Experimental Philosophy

ARE FULLY EXPLAINED.

VOL. III. OF OPTICS, MAGNETISM, ELECTRICITY, & GALVANISM.

"Conversation, with the habit of explaining the meaning of words
"and the structure of common domestic implements to children, is
"the sure and effectual method of preparing the mind for the ac-
"quirement of science." *Edgeworth's Practical Education.*

BY THE REV. J. JOYCE.

NEW EDITION CORRECTED AND IMPROVED.

PHILADELPHIA:
PUBLISHED BY M. CAREY, ISAAC PEIRCE, JOHNSON & WARNER, KIMBER & RICHARDSON, B. C. BUSBY, EMMOR KIMBER, BENNET & WALTON, EDWARD PARKER.

1815.

A. Griggs & K. Dickinson, Printers. *Whitehall.*

TO

ANNA LÆTITIA BARBAULD

AND

JOHN AIKIN, M. D.

AUTHORS

OF

"EVENINGS AT HOME,"

AND

OTHER ADMIRABLE WORKS

FOR

THE INSTRUCTION OF YOUNG PERSONS.

THE

THIRD VOLUME

OF

SCIENTIFIC DIALOGUES.

ARE

RESPECTFULLY INSCRIBED,

BY

THE AUTHOR.

ADVERTISEMENT.

IN presenting to the public the concluding volume of the SCIENTIFIC DIALOGUES, the Author cannot but acknowledge, with sentiments of gratitude, the favourable reception which the former parts of the work have experienced. He trusts that the several subjects comprised in this last volume, will have an equal claim to the candour of those who are engaged in the arduous but honourable employment of education.

It will be seen that it was quite impossible to include in the three volumes the introduction to chymistry, as it was originally intended. *This branch* of science is become *so very interesting*, and the study of it so

general, that it would have been unpardona ble to have devoted only a part of a volum to the discussion of it: the Author has therefore, at the suggestion and desire o many friends, who have given their appro bation to the Scientific Dialogues, underta ken to furnish a separate work on this sub ject, in two volumes, similar in size to this

OPTICS.

CONVERSATION I.

INTRODUCTION.

Of Light—The Smallness of its Particles—Their Velocity—They move only in straight Lines.

CHARLES. When we were on the sea, you told us that you would explain the reason why the oar, which was straight when it lay in the boat, appeared crooked as soon as it was put into the water.

Tutor. I did: but it requires some previous knowledge *before* you can *comprehend the subject.* It would afford you but

little satisfaction to be told that this decep tion was caused by the different degrees o *refraction* which takes place in water and i air.

James. We do not know what you mea by the word refraction.

Tutor. It will therefore be right to pro ceed with caution; *refraction* is a term fre quently used in the science of optics, an this science depends wholly on *light.*

James. What is light?

Tutor. It would, perhaps, be difficult t give a direct answer to your question, be cause we know nothing of the nature c light, but by the effects which it produces In reasoning, however, on this subject, it i generally admitted that light consists of in conceivably small particles; which are pro jected, or thrown off from a luminous bod with great velocity, in all directions.

Charles. But how is it known that light i composed of small particles?

Tutor. There is no proof indeed that ligh *is material,* or composed of particles of mat *ter, and therefore* I said it was generall

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James. And you say the particles of light move in all directions.

Tutor. Here is a sheet of thick brown paper, I make only a small pin-hole in it, and then through that hole, I can see all the objects, such as the sky, trees, houses, &c. as I could if the paper were not there.

Charles. Do we only see objects by means of the rays of light which flow from them?

Tutor. In no other way: and therefore the light that comes from the landscape, which I view by looking through the small hole in the paper, must come in all directions at the same time.—Take another instance; if a candle be placed on an eminence in a dark night, it may be seen all round for the space of half a mile: in other words, there is no place within a sphere of a mile in diameter, where the candle cannot be seen, that is, where some of the rays from the small flame will not be found.

James. Why do you limit the distance to *half a mile?*

Tutor. The distance, of course, will be greater or less, according to the size of the candle: but the degree of light, like heat, diminishes in proportion as you go farther from the luminous body.

Charles. Does it follow the same law as *gravity?**

Tutor. It does: the *intensity* or degree of light decreases as the square of the distance from the luminous body increases.

James. Do you mean, that at the distance of two yards from a candle, we shall have four times less light, than we should have, if we were only one yard from it?

Tutor. I do: and at three yards distance, nine times less light; and at four yards' distance you will have sixteen times less light than you would were you within a yard of the object.—I have one more thing to tell you: light always moves in straight lines.

James. How is that known?

* *See Scientific* Dialogues, Vol. I. Conversation *VII.*

Tutor. Look through a straight tube at any object, and the rays of light will flow readily from it to the eye, but let the tube be bent, and the object cannot be seen through it, which proves that light will move only in a straight line.

This is plain also from the shadows which opaque bodies cast; for if the light did not describe straight lines, there would be no shadow. Hold any object in the light of the sun, or a candle, as a square board or book, and the shadow caused by it proves that light moves only in right or straight lines.

CONVERSATION II.

Of Rays of Light—Of Reflection and Refraction.

CHARLES. You talked, the last time we met, of the rays of light flowing or moving, what do you mean by a *ray of light?*

Tutor. Light you know is supposed to be made up of indefinitely small particles; now one or more of these particles in motion from any body, is called a ray of light. —If the supposition be true, that light consists of particles flowing from a luminous body, as the sun, and that these particles are about eight minutes in coming

from the sun to us; then if the sun were blotted from the heavens, we should actually have the same appearance for eight minutes after the destruction of that body as we now have.

James. I do not understand how we could see a thing that would not exist.

Tutor. The sun is perpetually throwing off particles of light, which travel at the rate of twelve millions of miles in a minute, and it is by these that the image of the body is impressed on our eye. The sun being blotted from the firmament would not affect the course of the particles that had the instant before been thrown from his body, they would travel on as if nothing had happened, and till the last particles had reached the eye, we should think we saw the sun, as much as we do now.

Charles. Do we not actually see the body itself?

Tutor. *The sense of sight may, perhaps, not be unaptly* compared to that of

smell: a grain of musk will throw off its odoriferous particles all round, to a considerable distance, now if you or I happen to be near it, the particles which fall upon certain nerves in the nose will excite in us those sensations, by which we say we have the smell of musk. In the same way particles of light are flowing in every direction from the grain of musk, some of which fall on the eye, and these excite different sensations, from which we say, we see a piece of musk.

Charles. But the musk will in time be completely dissipated, by the act of throwing off the fine particles; whereas a chair or a table may throw off its rays so as to be visible, without ever diminishing its size.

Tutor. True: because whatever is distinguished by the sense of smell, is known only by the particles of the odoriferous body itself flowing from it: whereas a body distinguished by the sense of sight is known by the rays of light, which first

fall on the body, and are then *reflected* from it.

James. What do you mean by being *reflected?*

Tutor. If I throw this marble smartly against the wainscot, will it remain where it was thrown?

James. No: it will *rebound*, or come back again.

Tutor. What you call rebounding, writers on optics denominate *reflection.* When a body of any kind, whether it be a marble with which you play, or a particle of light, strikes against a surface, and is sent back again, it is said to be reflected. If you shoot a marble straight against a board, or other obstacle, it comes back in the same line, or nearly so; but suppose you throw it sideways, does it return to the hand?

Charles. Let me see: I will shoot this marble against the *middle* of one side of the room, from the corner of the opposite side.

James. You see, instead of coming back to your hand, it goes off to the other corner, directly opposite to the place from which you sent it.

Tutor. This will lead us to the explanation of one of the principal definitions in optics, viz. *that the angle of reflection is always equal to the angle of incidence.* You know what an angle is?*

Charles. We do: but not what an angle of *incidence* is.

Tutor. I said a ray of light was a particle of light in motion: now there are *incident* rays, and *reflected* rays.

The *incident* rays are those which *fall on* the surface; and the *reflected* rays are those which are *sent off* from it.

Charles. Does the marble *going to* the wainscot represent the *incident* ray, and in *going from* it, does it represent the *reflected* ray?

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* See Scientific Dialogues, Vol. I. Conversation I.

Tutor. It does: and the wainscot may be called the reflecting surface.

James. Then what are the angles of incidence and reflection?

Tutor. Suppose you draw the lines on which the marble travelled, both to the wainscot, and from it again.

Charles. I will do it with a piece of chalk.

Tutor. Now draw a perpendicular* from the point where the marble struck the surface, that is, where your two lines meet.

Charles. I see there are two angles, and they seem to be equal.

Tutor. We cannot expect mathematical precision in such trials as these; but if

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* If the point be exactly in the middle of one side of the room, a perpendicular is readily drawn by finding the middle of the opposite side, and joining the two points.

the experiment were accurately made, the two angles would be perfectly equal: the angle contained between the incident ray, and the perpendicular, is called the angle of incidence, and that contained between the perpendicular and reflected ray, is called the angle of reflection.

James. Are these in all cases equal, shoot the marble as you will?

Tutor. They are: and the truth holds equally with the rays of light:—both of you stand in front of the looking-glass. You see yourselves, and one another also; for the rays of light flow from you to the glass, and are reflected back again in the same lines. Now both of you stand on one side of the room. What do you see?

Charles. Not ourselves, but the furniture on the opposite side.

Tutor. The reason of this is, that the rays of light flowing from you to the glass, are reflected to the other side of the room.

Charles. Then if I go to that part, shall see the rays of light flowing from ny brother :—and I do see him in the lass.

James. And I see Charles.

Tutor. Now the rays of light flow rom each of you to the glass, and are re- lected to one another: but neither of you ees himself.

Charles. No: I will move in front of he glass, now I see myself, but not my rother; and, I think, I understand the ubject very well.

Tutor. Then explain it to me by a fi- ure, which you may draw on the slate.

Charles. Let A B (Plate I. Fig. 1.) epresent the looking-glass: if I stand at :, the rays flow from me to the glass, and re reflected back in the same line, because ow there is no angle of incidence, and of ourse no angle of reflection; but if I tand at *x*, then the rays flow from me

to the glass, but they make the a
x o c, and therefore they must be refle
in the line o y, so as to make the a
y o c, which is the angle of reflec
equal to the angle x o c. And if Ja
stand at y, he will see me at x, and I st
ing at x, shall see him at y.

CONVERSATION III.

Of the Refraction of Light.

CHARLES. If glass stop the rays of light, and reflect them, why cannot I see myself in the window?

Tutor. It is the silvering on the glass which causes the reflection, otherwise the rays would pass through it without being stopped, and if they were not stopped, they could not be reflected. No glass, however, is so transparent, but it reflects some rays: put your hand to within three or four inches of the window, and you see clearly the image of it.

James. So I do, and the nearer the hand is to the glass, the more evident is the im-

age, but it is formed on the other side of the glass, and beyond it too.

Tutor. It is; this happens also in looking-glasses: you do not see yourself on the surface, but apparently as far behind the glass, as you stand from it in the front.

Whatever suffers the rays of light to pass through it, is called a *medium.* Glass, which is transparent, is a medium; so also is air, water, and indeed all fluids that are transparent are called *media*, and the more transparent the body, the more perfect is the medium.

Charles. Do the rays of light pass through these in a straight line?

Tutor. They do: but not in precisely the same direction in which they were moving before they entered it. They are *bent* out of their former course, and this is called *refraction.*

James. Can you explain this term more clearly?

Tutor. Suppose A B (Plate I. Fig. 2.) to be a piece of glass, two or three inches thick; and a ray of light S *a*, to fall upon it

at *a*, it will not pass through in the direction S *s*, but when it comes to *a*, it will be bent towards the perpendicular *a b*, and go through the glass in the course *a x*, and when it comes into the air, it will pass on in the direction *x z*, which is parallel to S *s*.

Charles. Does this happen if the ray fall perpendicularly on the glass at P *a*?

Tutor. In that case there is no refraction, but the ray proceeds in its passage through the glass, precisely in the same direction as it did before it entered it, namely, in the direction P b.

James. Refraction then takes place only when the rays fall obliquely or slantwise on the medium?

Tutor. Just so: rays of light may pass out of a rarer into a denser medium, as from air into water or glass: or they may pass from a denser medium into a rarer, as from water into air.

Charles. Are the effects the same in both cases?

Tutor. They are not: and I wish you to remember the difference. When light

passes out of a rarer into a denser medium, it is drawn *to* the perpendicular; thus if s *a* pass from air into glass, it moves, in its passage through it, in the line *a x*, which is nearer to the perpendicular *a b* than the line *a* s, which was its first direction.

But when a ray passes from a denser medium into a rarer, it moves in a direction *farther from* the perpendicular; thus if the ray *x a* pass through glass or water into air, it will not, when it comes to *a*, move in the direction *a m*, but in the line *a* s, which is further than *a m* from the perpendicular *a* P.

James. Can you show us any experiment in proof of this?

Tutor. Yes, I can: here is a common earthen pan, on the bottom of which I will lay a shilling, and will fasten it with a piece of soft wax, so that it shall not move from its place, while I pour in some water. Stand back till you just lose sight of the shilling.

James. The side of the pan now completely hides the sight of the money from me.

Tutor. I will pour in a pitcher of clear water.

James. I now see the shilling: how is this to be explained?

Tutor. Look to the last figure, and conceive your eye to be at s, *a b* the side of the pan, and the piece of money to be at *x*: now when the pan is empty, the rays of light flow from *x*, in the direction *x a m*, but your eye is at s, of course you cannot see any thing by the ray proceeding along *x a m*. As soon as I put the water into the vessel, the rays of light proceed from *x* to *a*, but there they enter from a denser to a rarer medium; and therefore, instead of moving in *a m*, as they did when there was no water, they will be bent *from* the perpendicular, and will come to your eye at s, as if the shilling were situate at *n*.

James. And it does appear to me to be at *n*.

Tutor. Remember what I am going to tell you, for it is a sort of axiom in optics: "*We see every thing* in the *direction* of *that line in which* the rays approach us last."

Which may be thus illustrated: I plac
candle before the looking-glass, and if y
stand also before the glass, the image of
candle appears behind it; but if anot
looking-glass be so placed as to receive
reflected rays of the candle, and you sta
before this second glass, the candle will
pear behind that; because the mind tra
fers every object seen along the line
which the rays came to the eye last.

Charles. If the shilling were not mov
by the pouring in of the water, I do not u
derstand how we could see it afterwards.

Tutor. But you do see it now at t
point *n*, or rather at the little dot just abo
it, which is an inch or two from the pla
where it was fastened at the bottom, a
from which, you may convince yourself
has not moved.

James. I should like to be convinced
this: will you make the experiment aga
that I may be satisfied of it?

Tutor. You may make it as often as y
please, and the effect will always be
same; but you must not imagine tha

shilling only will appear to move, the bottom of the vessel seems also to change its place.

James. It appears to me to be raised higher as the water is poured in.

Tutor. I trust you are satisfied by this experiment: but I can show you another equally convincing; but for this we stand in need of the sun.

Take an empty vessel A, a common pan or basin will answer the purpose, (Plate I. Fig. 3.) into a dark room, having only a very small hole in the window shutter: so place the basin that a ray of light S *s* shall fall upon the bottom of it at *a*, here I make a small mark, and then fill the basin with water. Now where does the ray fall?

James. Much nearer to the side at *b*.

Tutor. I did not move the basin, and therefore could have had no power in altering the course of light.

Charles. It is very clear that the ray was refracted by the water at *s*: and I see that the effect of refraction in this instance has been to *draw the ray nearer to* a perpendicular, which may be conceived to be the side of the vessel.

Tutor. The same thing may be show
with a candle in a room otherwise dark : l
it stand in such a manner as that the sha
dow of the side of a pan or box may f
somewhere at the bottom of it ; mark t
place, and pour in water, and the shado
will not then fall so far from the side.

CONVERSATION IV.

f the Reflection and Refraction of Light.

TOR. We will proceed to some far-
llustrations of the laws of reflection
efraction. We shut out all the light
the ray that comes in at the small
the shutter: at the bottom of this
where the ray of light falls, I lay
ece of looking-glass; and if the wa-
rendered in a small degree opaque
xing with it a few drops of milk,
e room be filled with dust by sweep-
arpet, or any other means, then you
the refraction which the ray

from the shutter undergoes in passing int the water, the reflection of it at the surfac of the looking-glass, and the refractio which takes place when the ray leaves th water, and passes again into the air.

James. Does this refraction take place i all kinds of glass?

Tutor. It does; but where the glass i very thin, as in window glass, the devia tion is so small as to be generally overlook ed. You may now understand why th oar in the water appears bent, though it b really straight; for suppose A B (Plate Fig. 4.) represent water, and *m a x* th oar, the image of the part *a x* in the wate will lie above the object, so that the oa will appear in the shape *m a n*, instead c *m a x*. On this account also, a fish in th water appears nearer the surface than i actually is, and a marksman shooting at i must aim below the place which it seem to occupy.

Charles. Does the image of the objec seen in the water always appear highe the object really is?

Tutor. It appears one fourth nearer the surface than the object is. Hence a pond or river is a third part deeper than it appears to be, which is of importance to remember, for many a school-boy has lost his life by imagining the water into which he plunged was within his depth.

James. You say the bottom appears one *fourth* nearer the surface than it is; and then that the water is a *third* deeper than it seems to be: I do not understand this.

Tutor. Suppose the river to be six feet deep, which is sufficient to drown you or me, if we cannot swim: I say the bottom will appear to be only four feet and a half from the surface, in which case you could stand and have the greater part of your head above it; of course it appears to be a foot and a half shallower than it is; but a foot and a half is just the *third* part of four feet and a half.

Charles. Can this be shown by experiment?

Tutor. *It may*:—I take this large empty

pan, and with a piece of soft wax stick a piece of money at the bottom, but so that you can just see it as you stand; keep your position, and I will pour in a quantity of water gradually, and tell me the appearance.

Charles. The shilling rises exactly in the same proportion as you pour in the water.

Tutor. Recollect then, in future, that we cannot judge of *distances* so well in water as in air.

James. And I am sure we cannot of magnitudes: for in looking through the sides of a globular glass at some gold and silver fish, I thought them very large; but if I looked down upon them from the top, they appear much smaller indeed.

Tutor. Here the convex or round shape of the glass becomes a magnifier, the reason of which will be explained hereafter. A fish will, however, look larger in water than it really is.—I will show you another *experiment* which depends on refraction:

ere is a glass goblet two-thirds full of wa-
er; I throw into it a shilling, and place a
late on the top of it, and turn it quickly
ver, that the water may not escape. What
o you see?

Charles. There is certainly a half crown
ing on the plate, and a shilling seems
wimming above it in the water.

Tutor. So it appears indeed; but it is
deception which arises from your seeing
e piece of money in two directions at
nce, viz. through the conical surface of
he water at the side of the glass, and
hrough the flat surface at the top of the
vater. The conical surface, as was the
ase with the globular one in which the
ish were swimming, magnifies the money;
ut by the flat surface the rays are only re-
racted, on which account the money is seen
igher up in the glass, and of its natural
ize, or nearly so.

James. If I look sideways at the mo-
ey I only see the large piece; and if only
top, I see it in its natural size and state.

Charles. Look again at the fish in the glass, and you will see through the round part two very large fish, and seeing them from the upper part, they appear of their natural size; the deception is the same as with the shilling in the goblet.

Tutor. The principle of refraction is productive of some very important effects. By this the sun, every clear morning, is seen several minutes before he comes to the horizon, and as long after he sinks beneath it in the evening.

Charles. Then the days are longer than they would be if there was no such a thing as refraction. Will you explain how this happens?

Tutor. I will: you know we are surrounded with an atmosphere which extends all round the earth, and above it about the height of forty-five miles; now the dotted part of Fig. 5. represents that atmosphere: suppose a spectator stand at *s*, and the sun be at *a*; if there were no refraction, the person at *s* would not se

the rays of the sun till he were situate with regard to the sun in a line *s x a*; because when it was below the horizon at *b*, the rays would pass by the earth in the direction *b x z*; but owing to the atmosphere, and its refracting power, when the rays from *b* reach *x*, they are bent towards the perpendicular, and carried to the spectator at *s*.

James. Will he really see the image of the sun while it is below the horizon?

Tutor. He will; for it is easy to calculate the moment when the sun should rise and set, and if that be compared with exact observation, it will be found that the image of the sun is seen sooner and later than this by several minutes every clear day.

Charles. Are we subject to the same kind of deception when the sun is actually above the horizon?

Tutor. We are always subject to it in these latitudes, and the sun is never in that place in the heavens where he appears to be.

James. Why in these latitudes particularly?

Tutor. Because with us the sun is never in the *zenith*, s, or directly over our heads; and in that situation alone, his *true* place in the heavens is the same as his *apparent* place.

Charles. Is that because there is no refraction when the rays fall perpendicularly on the atmosphere?

Tutor. It is: but when the sun (Plate 1. Fig. 5.) is at *m*, his rays will not proceed in a direct line *m o r*, but will be bent out of their course at *o*, and go in the direction *o s*, and the spectator will imagine he sees the sun in the line *s o n*.

Charles. What makes the moon look so much larger when it is just above the horizon, than when it is higher up?

Tutor. The thickness of the atmosphere when the moon is near the horizon, renders it less bright than when it is higher up, which leads us to suppose it is farther off in the former case than in the latter:

nd because we imagine it to be farther from us, we take it to be a larger object than when it is higher up.

It is owing to the atmosphere that the heavens appear bright in the day time. Without an atmosphere, only that part of the heavens would appear luminous in which the sun is placed; in that case, if we could live without air, and should stand with our backs to the sun, the whole heavens would appear as dark as night.

CONVERSATION V.

Definitions—Of the different kind of Lenses—Of Mr. Parker's Burning Lens, and the effects produced by it.

TUTOR. I must claim your attention to a few other definitions; the knowledge of which will be wanted as we proceed.

A pencil of rays is any number that proceed from a point.

Parallel rays are such as move always at the same distance from each other.

Charles. That is something like the definition of *parallel lines*.* But when you

* *Parallel lines* are those which being infinitely extended never meet.

admitted the rays of light through the small hole in the shutter, they did not seem to flow from that point in parallel lines, but to recede from each other in proportion to their distance from that point.

Tutor. They did: and when they do thus recede from each other, as in this figure (Plate 1. Fig. 6.) from C to *c d*, then they are said to *diverge*. But if they continually approach towards each other as in moving from *c d* to C, they are said to *converge*.

James. What does the dark part of this figure represent?

Tutor. It represents a glass lens, of which there are several kinds.

Charles. How do you describe a lens?

Tutor. A *lens* is a glass ground into such a form as to collect or disperse the rays of light which pass through it. They are of different shapes, from which they take their names. They are represented here in *one view, (Plate* 1. Fig. 7.) A is *such a one as that in* the last figure, and it

is called a *plano-convex*, because one side is flat and the other convex; B is a *plano concave*, one side being *flat*, and the other is *concave*; C is a *double convex-lens*, because both sides are convex; D is a *double concave*, because both sides are concave; and E is called a *meniscus*, being convex on one side, and concave on the other; of this kind are all watch glasses.

James. I can easily conceive of diverging rays, or rays proceeding from a point; but what is to make them converge, or come to a point?

Tutor. Look again to the figure (Fig. 6.) now *a*, *b*, *m*, &c. represent parallel rays, falling upon *c d* a convex surface, of glass for instance, all of which, except the middle one, fall upon it obliquely, and, according to what we saw yesterday, will be refracted towards the perpendicular.

Charles. And I see they will all meet in a certain point in that middle line.

Tutor. That point C is called the *focus*: the dark part of this figure only represents the glass, as *c d n*.

Charles. Have you drawn the circle to show the exact curve of the different lenses?

Tutor. Yes: and you see that parallel rays falling upon a *plano-convex lens* (Fig. 6.) meet at a point behind it, the distance of which, from the middle of the glass, is exactly equal to the diameter of the sphere of which the lens is a portion.

James. And in the case of a *double convex*, is the distance of the focus of parallel rays, equal only to the radius of the sphere? (Plate 1. Fig. 8.)

Tutor. It is: and you see the reason of it immediately; for two concave surfaces have double the effect in refracting rays to what a single one has: the *latter* bringing them to a focus at the distance of the diameter, the former at half that distance, or of the radius.

Charles. Sometimes, perhaps, the two sides of the same lens may have different curves: what is to be done then?

Tutor. If you know the radius of both the curves, the following rule will give you the answer:

"As the sum of the radii of both curve or convexities is to the radius of either, so i double the radius of the other to the dis tance of the focus from the middle point.'

James. Then if one radius be fou inches, and the other three inches, I say as $4+3 : 4 :: 6 : \frac{24}{7}=3\frac{3}{7}$, or to nearly thre inches and a half. I saw a gentleman light ing his pipe yesterday by means of th sun's rays and a glass, was that a doubl convex lens?

Tutor. I dare say it was: and you now see the reason of that which then you could not comprehend: all the rays of the sun that fall on the surface of the glass (see Fig. 8.) are collected in the point *f*, which, in this case, may represent the tobacco in the pipe.

Charles. How do you calculate the heat which is collected in the focus?

Tutor. The force of the heat collected in the focus is in proportion to the common heat of the sun, as the area of the glass is to the area of the focus: of course, it may be a

red or even a thousand times greater in
ne case than in the other.

mes. Have I not heard you say that
Parker, of Fleet-street, made once a
large lens, which he used as a burning-
?

tor. He formed one three feet in di-
er, and when fixed in its frame, it ex-
a clear surface of more than two feet
inches in diameter, and its focus, by
s of another lens, was reduced to a
eter of half an inch. The heat pro-
d by this was so great, that iron plates
melted in a few seconds: tiles and
s became red-hot in a moment, and
vitrified, or changed into glass: sul-
, pitch, and other resinous bodies,
melted under water: wood-ashes, and
e of other vegetable substances, were
ed in a moment into transparent glass.

harles. Would the heat produced by it
all the metals?

utor. It would: even gold was ren-
fluid in a few seconds; notwithstand-
owever, this intense heat at the focus,

the finger might, without the smalles jury, be placed in the cone of rays wi an inch of the focus.

James. There was, however, I sh suppose, some risque in this experim for fear of bringing the finger too near focus.

Tutor. Mr. Parker's curiosity led to try what the sensation would be at focus; and he describes it like that duced by a sharp lancet, and not at al milar to the pain produced by the he fire or a candle. Substances of a w colour were difficult to be acted upon

Charles. I suppose he could make w boil in a very short time with the lens.

Tutor. If the water be very pure contained in a clear glass decanter, it not be warmed by the most powerful But a piece of wood may be burned coal, when it is contained in a decant water.

James. Will not the heat break glass?

Tutor. It will scarcely warm it: if, however, a piece of metal be put in the water, and the point of rays be thrown on that, it will communicate heat to the water, and sometimes make it boil. The same effect will be produced if there be some ink thrown into the water.

If a cavity be made in a piece of charcoal, and the substance to be acted on be put in it, the effect produced by the lens will be much increased. Any metal thus enclosed melts in a moment, the fire sparkling like that of a forge to which the blast of a bellows is applied.

CONVERSATION VI.

Of Parallel Rays—Of diverging and converging Rays
Of the Focus and focal distances.

CHARLES. I have been looking at the figures 6 and 8, and see that the rays falling upon the lenses are parallel to one another: are the sun's rays parallel?

Tutor. They are considered so: but you must not suppose that all the rays that come from the surface of an object, as the sun, or any other body, to the eye, are parallel to each other, but it must be understood of those rays only which proceed from a single point. Suppose S (Plate I. Fig. 9.) to be the sun, the rays which proceed from a single point A, do in reality form a cone, the

base of which is the pupil of the eye, and its height is the distance from us to the sun.

James. But the breadth of the eye is nothing when compared to a line ninety-five millions of miles long.

Tutor. And for that reason, the various rays that proceed from a single point in the sun are considered as parallel, because their inclination to each other is insensible. The same may be said of any other point as C. Now all the rays that we can admit by means of a small aperture or hole, must proceed from an indefinitely small point of the sun, and therefore they are justly considered as parallel.

If now we take a ray from the point A, and another from C, on opposite points of the sun's disk, they will form a sensible angle at the eye; and it is from this angle A E C that we judge of the apparent size of the sun, which is about half a degree in diameter.

Charles. Will the size of the pupil of the eye make any difference with regard to the appearance of the object?

Tutor. The larger the pupil, the brighter will the object appear, because the larger the pupil is, the greater number of rays it will receive from any single point of the object.—And I wish to remember what I have told you before, that whenever the appearance of a given object is rendered larger and brighter, we always imagine that the object is nearer to us than it really is, or than it appears at other times.

James. If there be nothing to receive the rays (Fig. 8.) at *f*, would they cross one another and diverge?

Tutor. Certainly, in the same manner as they converged in coming to it; and if another glass F G, of the same convexity as D E, be placed in the rays at the same distance from the focus, it will so refract them, that, after going out of it, they will be parallel, and so proceed on in the same manner as they came to the first glass.

Charles. There is, however, this difference; all the rays, except the middle one, have changed sides.

Tutor. You are right, the ray B, which entered at bottom, goes out at the top *b*; and A, which entered at the top, goes out at the bottom *c*, and so of the rest.

If a candle be placed at *f*, the focus of the convex glass, the diverging rays in the space F *f* G, will be so refracted by the glass, that after going out of it, they will become parallel again.

James. What will be the effect if the candle be nearer to the glass then the point *f*?

Tutor. In that case, as if the candle be at *g*, (Plate II. Fig. 10.) the rays will diverge after they have passed through the glass, and the divergency will be greater or less in proportion as the candle is more or less distant from the focus.

Charles. If the candle be placed farther from the lens than the focus *f*, will the rays meet in a point after they have passed through it?

Tutor. They will: thus if the candle be placed at *g*, (Plate II. Fig. 11.) the rays, after passing the lens, will meet at *x*; and this point *x* will be *more* or less distant from

the glass, as the candle is *nearer* to, or farther from its focus. Where the rays meet, they form an *inverted* image of the flame of the candle.

James. Why so?

Tutor. Because that is the point where the rays, if they are not stopped, cross each other: to satisfy you on this head, I will hold in that point a sheet of paper, and you now see that the flame of the candle is inverted.

James. How is this explained?

Tutor. Let A B C (Plate II. Fig. 12.) represent an arrow placed beyond the focus F, of a double convex lens *d e f*, some rays will flow from every part of the arrow, and fall on the lens; but we shall consider only those which flow from the points A, B, and C. The rays which come from A, as A *d*, A *e*, and A *f*, will be refracted by the lens, and meet in A. Those which come from B, as B *d*, B *e*, and B *f*, will unite in *b*, and those which come from C, will unite in C.

Charles. I see clearly how the rays from B are refracted, and unite in *b*; but it is n

so evident with regard to those from the extremities A and C.

Tutor. I admit it; but you must remember the difficulty consists in this, the rays fall more obliquely on the glass from those points than from the middle, and therefore the refraction is very different. The ray B F in the centre suffers no refraction, B *d* is refracted into *b*; and if another ray went from N, as N *d*, it would be refracted to *n*, somewhere between *b* and *a*, and the rays from A must, for the same reason, be refracted to *a*.

James. If the subject A B C is brought nearer to the glass, will the picture be removed to a greater distance?

Tutor. It will: for then the rays will fall more diverging upon the glass, and cannot be so soon collected into the corresponding points behind it.

Charles. From what you have said, I see that if the object A B C be placed in F, the rays, after refraction, will go out parallel to one another; and if brought nearer to the glass than F, then they will diverge from

one another, so that in neither case an image will be formed behind the lens.

James. To get an image, must the object be beyond the focus F?

Tutor. It must: and the picture will be bigger or less than the object, as its distance from the glass is greater or less than the distance of the object; if A B C (Fig. 12.) be the object, C *b* A will be the picture; and if C *b* A be the object, A B C will be the picture.

Charles. Is there any rule to find the distance of the picture from the glass?

Tutor. If you know the focal distance of the glass, and the distance of the object from the glass, the rule is this:

"Multiply the distance of the focus, by the distance of the object, and divide the product by their difference, the quotient is the distance of the picture."

James. If the focal distance of the glass be seven inches, and the object be nine inches from the lens, I say,

$\frac{7\times 9}{2}=\frac{63}{2}=31\frac{1}{2}$ inches of course the picture will be very much larger than the ob-

For, as you have said, the picture is
uch bigger or, less than the object, as its
nce from the glass is greater or less
the distance of the object.

utor. If the focus be seven inches, and
bject at the distance of seventeen inches,
the distance of the picture will be found

$$\frac{7 \times 17}{10} = \frac{119}{10} = 12 \text{ inches nearly.}$$

window shutter of a room from
light is excluded except what
through this glass.

Charles. Of what does this i
consist?

Tutor. Of a frame A B (Plat
13.) and a ball of wood C, in
glass lens; and the ball moves ea
frame in all directions, so that th
any surrounding objects may b
through it.

James. Do you screw this f
the shutter?

Tutor. Yes, a hole is cut in
purpose; and there are little brass
longing to it, such as those marke
it is fixed in its place, a screen m
at a proper distance from the lens
on it images of the objects out
This instrument is sometimes cal
tificial eye.

Charles. In what respects is
eye?

Tutor. The frame has been
to the socket in which the eye m

the wooden ball to the whole globe of the eye; the whole in the ball represents the pupil, the convex lens corresponds to the crystaline humour,* and the screen to the retina.

James. The ball by turning in all directions is very like the eye, for without moving the head I can look on all sides, and upwards and downwards.

Tutor. Well, we will now place the screen properly, and turn the ball to the garden:—Here you see all the objects perfectly expressed.

James. But they are all inverted.

Tutor. That is the great defect belonging to this instrument; but I will tell you how it may be remedied: take a looking-glass and hold it before you with its face towards the picture on the screen, and inclining a little downwards, and the images will appear erect in the glass, and even brighter than they were on the screen.

* These terms will be explained hereafter.

Charles. You have shown us in w
manner the rays of light are refracted
convex lenses, when those rays are paral
Will there not be a difference if the rays *c*
verge, or *diverge* before they enter the le

Tutor. Certainly: if rays *converge*
fore they enter a convex lens, they will
collected at a point *nearer* to the lens th
the focus of parallel rays. But if they
verge before they enter the lens, they
then be collected in a point *beyond* the fo
of parallel rays.

There are concave lenses as well as c
vex, and the refraction which takes place
means of these differs from that whic
have already explained.

Charles. What will the effect of refr
tion be, when parallel rays fall upon a d
ble concave lens?

Tutor. Suppose the parallel rays *a*, *b*, *c*
&c. (Plate II. Fig. 14.) pass through
lens A B, they will *diverge* after they h
passed through the glass.

James. Is there any rule for ascertain
the degree of divergency?

Tutor. Yes; it will be precisely so much as if the rays had come from a radiant point x, which is the centre of the concavity of the glass.

Charles. Is that point called the focus?

Tutor. It is called the *virtual* or *imaginary focus*. Thus the ray *a*, after passing through the glass A B, will go on in the direction *g h*, as if it had come from the point x, and no glass been in the way: the ray *b*, would go on in the direction *m n*. and the ray *e* in the direction *r s*, and so on. The ray C X in the centre suffers no refraction, but proceeds precisely as if no glass had been in the way.

James. Suppose the lens had been concave only on one side, and the other side had been flat, how would the rays have diverged?

Tutor. They would have diverged after passing through it, as if they had come from a radiant point at the distance of a whole diameter of the convexity of the lens.

Charles. There is then a great similarity

in the refraction of the convex and con
lens.

Tutor. True: the *focus* of a double
vex is at the distance of the radius of
vexity, and so is the *imaginary focus* of
double concave; and the *focus* of the pla
convex is at the distance of the diamete
the convexity, and so is the *imaginary f*
of the plano concave.

You will find that images formed b
concave lens, or those formed by a con
lens, where the object is *within* its princ
focus, are in the same position with the
jects they represent: they are also *imagi*
ry, for the refracted rays never meet at
foci whence they seem to diverge.

But the images of objects placed bey
the focus of a convex lens are inverted,
real, for the refracted rays do meet at t
proper foci.

CONVERSATION VIII.

Of the Nature and Advantages of Light——Of the Separation of the Rays of Light by means of a Prism——And of compounded Rays, &c.

TUTOR. We cannot contemplate the ature of light without being struck with he great advantages which we enjoy from . Without that blessing our condition ould be truly deplorable.

Charles. I well remember how feelingly Milton describes his situation after he lost is sight:

——————With the year
Seasons *return; but not to me returns*

Day, or the sweet approach of ev'n or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks, or herds, or human face divine;
But cloud instead, and ever-during dark
Surrounds me, from the cheerful ways of men
Cut off, and for the book of knowledge fair,
Presented with an universal blank
Of Natures works, to me expung'd and raz'd,
And wisdom, at one entrance, quite shut out.

Tutor. Yet his situation was rendered comfortable by means of friends and relations, who all possessed the advantages of light. But if our world were deprived of light, what pleasure or even comfort could we enjoy. "How," says a good writer, "could we provide ourselves with food, and the other necessaries of life? How could we transact the least business? How could we correspond with each other, or be of the least reciprocal service without light, and those admirable organs of the body, which the Omnipotent Creator has

adapted to the perception of this inestimable benefit?"

James. But you have told us that the light would be of comparatively small advantage without an atmosphere.

Tutor. The atmosphere not only *refracts* the rays of the light, so that we enjoy longer days than we should without it, but occasions that twilight, which is so beneficial to our eyes; for without it the appearance and disappearance of the sun would have been instantaneous; and in every twenty-four hours we should have experienced a sudden transition from the brightest sun-shine to the most profound darkness, and from thick darkness to a blaze of light.

Charles. I know how painful that would be, from having slept in a very dark room, and having suddenly opened the shutters when the sun was shining extremely bright.

Tutor. The atmosphere reflects also the light in every direction, and if there were no atmosphere, the sun would benefit

those only who looked towards it, and to those whose backs were turned to that luminary it would all be darkness. Ought we not therefore gratefully to acknowledge the wisdom and goodness of the Creator, who has adapted these things to the advantage of his creatures; and may we not with Thomson devoutly exclaim :

How then shall I attempt to sing of Him
Who, light himself, in uncreated light
Invested deep, dwells awfully retir'd
From mortal eye, or angel's purer ken;
Whose single smile has, from the first of time,
Fill'd, overflowing, all yon lamps of heaven,
That beam for ever through the boundless sky:
But, should He hide his face, th' astonish'd sun,
And all the extinguish'd stars would loosening reel
Wide from their spheres, and Chaos come again.—

James. I saw in some of your experiments that the rays of light, after passing through the glass, were tinged with different colours, what is the reason of this?

Tutor. Formerly light was supposed to be a simple and uncompounded body; Sir Isaac Newton, however, discovered that it was not a simple substance, but was composed of several parts, each of which has in fact a different degree of refrangibility.

Charles. How is that shown?

Tutor. Let the room be darkened, and let there only be a very small hole in the shutter to admit the sun's rays; instead of a lens I take a triangular piece of glass, called a *prism;* now as in this there is nothing to bring the rays to a focus, they will, in passing through it, suffer different degrees of refraction, and be separated into the different coloured rays, which being received on a sheet of white paper will exhibit the seven following colours: *red, orange, yellow, green, blue, indigo,* and *violet;* and now you shall hear a poet's description of them.

——————First the flaming *red*
Sprung vivid forth; the tawny *orange* next:
And next delicious *yellow*; by whose side
Fell the kind beams of all-refreshing *green*.
Then the pure *blue*, that swells autumnal skie
Ethereal play'd; and then of sadder hue,
Emerg'd the deepen'd *indigo*, as when
The heavy skirted evening droops with frost,
While the last gleamings of refracted light
Dy'd in the fainting *violet* away.

THOM

James. Here are all the colours o rainbow: the image on the paper is of oblong.

Tutor. That oblong image is u called a *spectrum*, and if it be divide 360 equal parts, the red will o forty-five of them, the orange twen ven, the yellow forty-eight, the gree the blue sixty each, the indigo fort *the violet* eighty.

Charles. The shade of difference in some of these colours seems very small indeed.

Tutor. You are not the only person who has made this observation; some experimental philosophers say there are but three original and truly distinct colours, viz, the *red*, *yellow*, and *blue*.

Charles. What is called the *orange* is surely only a mixture of the red and yellow, between which it is situated.

Tutor. In like manner the green is said to be a mixture of the yellow and blue, and the violet is but a fainter tinge of the indigo.

James. How is it then that light which consists of different colours, is usually seen as white?

Tutor. By mixing the several colours in due proportion white may be produced.

James. Do you mean to say that a mixture of red, orange, yellow, green, blue,

indigo, and violet, in any proportion, will produce a white?

Tutor. If you divide a circular surface into 360 parts, and then paint it in the proportion just mentioned, that is, forty-five of the parts red, twenty-seven orange, forty-eight yellow, &c. and turn it round with great velocity, the whole will appear of a dirty white, and if the colours were more perfect the white would be so too.

James. Was it then owing to the separation of the different rays, that I saw the rainbow colours about the edges of the image made with the lens?

Tutor. It was: some of the rays were scattered, and not brought to a focus, and these were divided in the course of refraction. And I may tell you now, though I shall not explain it at present, that the rainbow in the heavens is caused by the separation of the rays of light into their component parts.

Charles. And was that the cause of the colours which we saw on some soap bubbles which James was making with a tobacco-pipe?

Tutor. It was.

CONVERSATION IX.

Of Colours.

CHARLES. After what you said yesterday, I am at a loss to know the cause of different colours; the cloth on this table is green; that of which my coat is made is blue, what makes the difference in these? Am I to believe the poet, that

Colours are but phantoms of the day,
With that they're born, with that they fade away;
Like beauty's charms, they but amuse the sight,
Dark in themselves, till by reflection bright;
With the sun's aid to rival him they boast,
But light withdraw, in their own shades are lost.

HUGHES.

Tutor. All colours are supposed to exist only in the light of luminous bodies, such as the sun, a candle, &c. and that light falling incessantly upon different bodies is separated into its seven primitive colours, some of which are absorbed, while others are reflected.

James. Is it from the reflected rays that we judge of the colour of objects?

Tutor. It has generally been thought so; thus the cloth on the table absorbs all the rays but the green, which it reflects to the eye; but your coat is of a different texture, and absorbs all but the blue rays.

Charles. Why is paper and the snow white?

Tutor. The whiteness of paper is occasioned by its reflecting the greatest part of all the rays that fall upon it. And every flake of snow being an assemblage of frozen globules of water sticking together, reflects and refracts the light that falls upon it in all directions so as to mix it very intimately, and produce a white image on the eye.

James. Does the whiteness of the sun's

light arise from a mixture of all the pr
colours?

Tutor. It does, as may be easily p
by an experiment, for if any of the
colours be intercepted at the lens, the
in a great measure loses its whiteness.
the prism I will divide the ray into its
colours,* I will then take a convex l
order to re-unite them into a singl
which will exhibit a round image of
ning white; but if only five or six of
rays be taken with the lens, it will pro
dusky white.

Charles. And yet to this white col
the sun we are indebted for all the fi
lours exhibited in nature:

Fairest of beings! first created light!
Prime cause of beauty! for from thee alone,
The sparkling gem, the vegetable race,
The nobler worlds that live and breathe, their c
The lovely hues peculiar to each tribe,
From thy unfailing source of splendour draw.

MAL

* A figure will be given on this subject with
Conversation XVIII. on the Rainbow.

Tutor. These are very appropriate lines, for without light the diamond would lose all its beauty.

James. The diamond, I know, owes its brilliancy to the power of reflecting almost all the rays of light that fall on it: but are vegetable and animal tribes equally indebted to it?

Tutor. What does the gardener do to make his endive and lettuces white?

Charles. He ties them up.

Tutor. That is, he shuts out the light, and by this means they become blanched. I could produce you a thousand instances to show, not only that the colour, but even the existence of vegetables, depend upon light. Close wooded trees have only leaves on the outside, such is the cedar in the garden. Look up the inside of a yew tree, and you will see that the inner branches are almost, or altogether barren of leaves. Geraniums and other green-house plants turn their flowers to the light; and plants in general, if doomed to darkness, soon sicken and die.

James. There are some flowers, the petals of which are, in different parts, of different colours, how do you account for this?

Tutor. The flower of the hearts-ease is of this kind, and if examined with a good microscope, it will be found that the *texture* of the blue and yellow parts is very different. The texture of the leaves of the white and red rose is also different. Clouds also which are so various in their colours are undoubtedly more or less dense, as well as being differently placed with regard to the eye of the spectator; but the whole depends on the light of the sun for their beauty, to which the poet refers :—

> But see, the flush'd horizon flames intense
> With vivid red, in rich profusion stream'd
> O'er heaven's pure arch. At once the clouds assume
> Their gayest liveries; *these* with silvery beams
> Fring'd lovely; splendid *those* in liquid gold:
> And speak their sovereign's state. He comes, behold
> Fountain of light and colour, warmth and life!
> The king of glory!
>
> MALLET.

Charles. Are we to understand that colours depend on the reflection of the several coloured rays of light?

Tutor. This seems to have been the opinion of Sir Isaac Newton; but he concluded from various experiments on this subject, that every substance in nature, provided it be reduced to a proper degree of thinness, is transparent. Many transparent media reflect one colour, and transmit another: gold-leaf reflects the yellow, but it transmits a sort of green colour by holding it up against a strong light.

Mr. Delaval, a gentleman who a few years since made many experiments to ascertain how colours are produced, undertakes to show that they are exhibited by transmitted light alone, and not by reflected light.

James. I do not see how that can be the case with bodies that are not transparent.

Tutor. He infers, from his experiments, which you may hereafter examine for yourselves, that the original fibres of all substances, when cleared of heterogeneous matter, are perfectly white, and that the rays of light are reflected from these white parti-

cles through the colouring matter
which they are covered, and that
colouring matter serves to intercep
tain rays in their passage through it,
a free passage being left to others
will exhibit, according to these circur
ces, different colours.—The red colo
the shells of lobsters after boiling, he
is only a superficial covering spread
the white calcareous earth, of whic
shells are composed, and may be re
by scraping or filing. Before the appli
of heat it is so thick as to appear blac
ing too thick to admit the passage of li
the shell and back again. The case
same with feathers, which owe their c
to a thin layer or transparent matte
white ground.

CONVERSATION X.

Reflected Light, aud Plain Mirrors.

TUTOR. We now come to treat of a different species of glasses, viz. *mirrors*, of or, as they are sometimes called, specula.

James. A looking-glass is a mirror, is it not?

Tutor. Mirrors are made of glass, silvered on one side; they are also made of highly polished metal. There are three kinds of mirrors, the *plain*, the *convex*, and the *concave*.

Charles. You have shown us that in a looking-glass or plain mirror, "The angle

" of reflection is always equal to th
" of incident."*

Tutor. This rule is not only ap
to plain mirrors, but to those which a
vex and concave also, as I shall sh
to-morrow. But I wish to make so
servations first on plain mirrors.
first place, if you wish to see the c
image of yourself in a plain mirror o
ing-glass, it must be *half* as long as
high.

James. I should have imagined th
must have been as long as I am hig

Tutor. In looking at your imag
glass, does it not seem to be as far
the glass as you stand before it.

James. Yes: and if I move forw
backwards, the image behind the glas
to approach or recede.

Tutor. Let *a b* (Plate II. Fig.
the looking-glass, and A the spectator
ing opposite to it. The ray from

---

* See p. 16.

will be reflected in the same line A *a*, but the ray C *b* flowing from his foot, in order to be seen at the eye, must be reflected by the line *b* A.

Charles. So it will, for if *x b* be a line perpendicular to the glass, the incident angle will be *c b x*, equal to the reflected angle A *b x*.

Tutor. And therefore the foot will appear behind the glass at D along the line A *b* D, because that is the line in which the ray last approaches the eye.

James. Is that part of the glass *a b* intercepted by the lines A B and A D, equal exactly to half the lengh of B D, or A C?

Tutor. It is; A *a b* and A B D may be supposed to form two triangles, the sides of which always bear a fixed proportion to one another; and if A B is double of A *a*, as, in this case it is, B D will be double of *a b*, or at least of that part of the glass intercepted by A B and A D.

Charles. This will hold true, I see, stand at what distance we please from the glass.

Tutor. If you walk towards a look
glass, your image will approach, but w
double velocity, because the two motion
equal and contrary. But if, while you s
before a looking-glass, your brother
up to you from behind, his image wil
pear to you to move at the same rate
walks, but to him the velocity of the i
will appear to be double; for with re
to you, there will be but one motion, but
regard to him, there will be two equa
contrary ones.

James. If I look at the reflection
candle in a looking-glass, I see in fact
images, one much fainter than the
what is the reason of this?

Tutor. The same may be observ
any object that is strongly illuminated
the reason of the double image is, that
of the rays are immediately reflected
the upper surface of the glass which
the faint image, while the greater p
them are reflected from the farther su
or silvering part, and form the vivid i
To see these two images you must s

side sideways, and not directly before the glass.

Charles. What is meant by the expression of "An image being formed behind a reflector?"

Tutor. It is intended to denote that the reflected rays come to the eye with the same inclination as if the object itself were actually behind the reflector. If you, standing on one side of the room, see the image of your brother, who is on the other side, in the looking-glass, the image seems to be formed behind the glass, that is, the rays come to your eye precisely in the same way as they would if your brother himself stood in that place, without the intervention of a glass.

James. But the image in the glass is not so bright or vivid as the object.

Tutor. A plain mirror is in theory supposed to reflect all the light which falls upon it, but in practice nearly half the light is lost on account of the inaccuracy of the polish, &c.

Charles. Has it not been said, that Archi-

medus, at the seige of Syracuse, burned the ships of Marcellus, by a machine composed of mirrors?

Tutor. Yes: but we have no certain accounts that may be implicitly relied on. Mr. Buffon, about fifty or sixty years ago, burned a plank at the distance of seventy feet, with forty plain mirrors.

James. I do not see how they can act as burning glasses.

Tutor. A plain mirror reflects the light and heat coming from the sun, and will illuminate and heat any substance on which they are thrown, in the same manner as if the sun shone upon it. Two mirrors will reflect on it a double quantity of heat; and if 40 or 100 mirrors could be so placed as to reflect from each the heat coming from the sun, on any particular substance, they would increase the heat 40 or 100 times.

CONVERSATION XI.

Of Concave Mirrors----their Uses----how they act.

JAMES. To what uses are concave mirrors applied?

Tutor. They are chiefly used in reflecting telescopes; that is, in tellescopes adapted to viewing the heavenly bodies. And as you like to look at Jupiter's little moons and Saturn's ring through my tellescope, it may be worth your while to take some pains to know by what means this pleasure is afforded you.

Charles. I shall not object to any attention necessary to comprehend the principles on which these instruments are formed.

Tutor. A B (Plate II. Fig. 16.) represents a concave mirror, and *a b*, C *d*, *e f*, three parallel rays of light falling upon it. C is the centre of concavity, that is, one leg of your compasses being placed on C, and then open them to the length C *d*, and the other leg will touch the mirror A B in all its parts.

James. Then all the lines drawn from C to the glass will be equal to one another, as C *b*, C *d*, and C *f*?

Tutor. They will: and there is another property belonging to them; they are all perpendicular to the glass in the parts where they touch.

Charles. That is C *b*, and C *f* are perpendicular to the glass at *b* and *f*, as well as C *d* at *d*.

Tutor. Yes, they are:—C *d* is an *incident* ray, but as it passes through the centre of concavity, it will be reflected back in the same line, that is, as it makes no angle of incidence, so there will be no angle of reflection: *a b* is an *incident* ray, and I want to *know what* will be the direction of the re-*ed ray?*

Charles. Since c *b* is perpendicular to the glass at *b*, the angle of incidence is *a b* c; and as the angle of reflection is always equal to the angle of incidence, I must make another angle, as c *b m*, equal to *a b* c,* and then the line *b m* is that in which the incident ray will move after reflection.

Tutor. Can you, James, tell me how to find the line in which the incident ray *e f* will move after reflection?

James. Yes: I will make the angle c *f m* equal to c *f e*, and the line *f m* will be that in which the reflected ray will move; therefore *e f* is reflected to the same point *m* as *a b* was.

Tutor. If, instead of two incident rays, any number were drawn parallel to c *d*, they would every one be reflected to the same point *m*; and that point which is called the

* To make an angle c *b m*, equal to another given one, as *a b* c. From *b* as a centre with any radius *b x*, describe the arc *x o*, which will cut c *b* in *z*, take the distance *x z in your compasses, and* set off with it *z o*, and then draw the line *b o* m, and the angle m *b* c is equal to the angle *a b* c.

focus of parallel rays is distant from mirror equal to half the radius c *d*.

James. Then we may easily find the without the trouble of drawing the a merely by dividing the radius of conc into two equal parts.

Tutor. You may.—The rays, as we already observed, which proceed from point of a celestial object may be este parallel at the earth, and therefore the i of that point will be formed at *m*,

Charles. Do you mean that all the flowing from a point of a star, and f upon such a mirror, will be reflected t point *m*, where the image of the sta appear?

Tutor. I do, if there be any thing point *m* to receive the image.

James. Will not the same rule hold regard to terrestrial objects?

Tutor. No: for the rays which pr from any terrestrial object, however re *cannot be* esteemed strictly parallel *therefore come diverging*; and will

converged to a *single point*, at the distance of half the radius of the mirror's concavity from the reflecting surface; but in *separate points*, at a little greater distance from the mirror than half the radius.

Charles. Can you explain this by a figure?

Tutor. I will endeavour to do so. Let A B (Plate II. Fig. 17.) be a concave mirror, and M E any remote object, from every part of which rays will proceed to every point of the mirror; that is, from the point M rays will flow to every point of the mirror, and so they will from E, and from every point between these extremities. Let us see where the rays that proceed from M to A, *c*, and B will be reflected, or, in other words, where the image of the point M will be formed.

James. Will all the rays that proceed from M, to different parts of the glass, be reflected to a single point?

Tutor. Yes, they will, and the difficulty is to find that point: I will take only three rays *to prevent confusion, viz.* M A, M C, M B; and *is the centre of* concavity of the glass.

Charles. Then if I draw C A, that li
be perpendicular to the glass at the p
the angle M A C is now given, and it is
gle of incidence.

James. And you must make anothe
to it as you did before.

Tutor. Very well: make C A *x* e
M A C, and extend the line A *x*
length you please.

Now you have an angle M *c* C mac
the ray M *c*, and the perpendicular C *c*,
is another angle of incidence.

Charles. I will make the angle of
tion C *c* z equal to it, and the line *c* z
produced, cuts the line A *x* in a par
point, which I will call *m*.

Tutor. Draw now the perpendicul
and you have with it, and the ray M
angle of incidence M B C: make anot
gle equal to it, as its angle of reflecti

James. There it is C B *u*, and I f
line B *u* meets the other lines at the p

Tutor. Then *m* is the point in wh
the reflected rays of M will conver

urse the image of the extremity M of the row E M will be formed at *m*. Now the me might be shown of every other part of e object M E, the image of which will be presented by *e m*, which you see is at a greater distance from the glass than half c c, or radius.

Charles. The image is *inverted* also, and less than the object.

CONVERSATION XII.

Of Concave Mirrors, and Experiments on them,

TUTOR. If you understand what we conversed on yesterday, and what you have yourselves done, you will easily see how the image is formed by the large concave mirror of the reflecting telescope, when we come to examine the construction of that instrument. In a concave mirror the image is *less* than the object, when the object is more remote from the mirror than C, the centre of concavity, and in that case the image is b[illegible]n the object and mirror.

Jam[illegible]. Suppose the object be placed in the *centre* C?

Tutor. Then the image and object will coincide: and if the object is placed nearer to the glass than the centre c, then the image will be more remote, and bigger than the object.

Charles. I should like to see this illustrated by an experiment.

Tutor. Well, here is a large concave mirror: place yourself before it, beyond the centre of the concavity; and with a little care in adjusting your position, you will see an inverted image of yourself in the air between you and the mirror, and of a less size than you are. When you see the image, extend your hand gently towards the glass, and the hand of the image will advance to meet it till they both meet in the centre of the glass's concarity. If you carry your hand still farther, the hand of the image will pass by it, and come between it and the body: now move your hand to either side, and the image of it will move towards the other.

James. Is there any rule for finding the

Charles. Is the image then behind the mirror?

Tutor. It is; and farther behind the mirror than the object is before it. Let A C (Plate III. Fig. 18.) be a mirror, and *x* Z the object between the centre K of the glass, and the glass itself; and the image *x y* z will be behind the glass erect, curved, and magnified, and of course the image is farther behind the glass than the object is before it.

James. What would be the effect if, instead of an opaque object *x* Z, a luminous one, as a candle, were placed in the focus of a concave mirror?

Tutor. It would strongly illuminate a space of the same dimension as the mirror to a great distance: and if the candle were still nearer the mirror than the focus, its rays will enlighten a larger space. Hence you may understand the construction of many of the lamps which are now to be seen in many parts of London, and which are undoubtedly a great improvement in lighting the streets.

CONVERSATION XIII.

Of Concave and Convex Mirrors.

TUTOR. We shall devote another morning or two to the subject of reflection from mirrors of different kinds.

Charles. You have not said any thing about *convex* mirrors, and yet they are now very much in fashion in handsome drawing-rooms: I have seen several, and always observed that the image was very much less than the object.

Tutor. A convex mirror is an ornamental piece of furniture, especially if it can be placed before a window, either with a good

prospect, or where there are a number of persons passing and repassing in their different employments. The images reflected from these are smaller than the objects, erect, and behind the surface, therefore a landscape or a busy scene delineated on one of them, is always a beautiful object to the eye. For the same reason a glass of this kind in a room in which large assemblies meet, forms an extremely interesting picture. You may easily conceive how the convex mirror diminishes objects, or the images of objects, by considering in what manner they are magnified by the concave mirror. If *x y z* (Fig. 18.) were a straight object before a *convex* mirror A C, the image by reflection would be *x z*.

James. Would it not appear curved?

Tutor. Certainly: for if the object be a right line, or a plain surface, its image must be curved, because the different points of the object are not equally distant from the reflector. In fact, the images formed by convex mirrors, if accurately compared with the objects, are never exactly of the same shape.

Charles. I do not quite comprehend in what manner reflection takes place at a convex mirror.

Tutor. I will endeavour by a figure to make it plain: C D (Plate III. Fig. 19.) represents a convex mirror standing at the end of a room, before which the arrow A B is placed on one side or obliquely: where must the spectator stand to see the reflected image?

Charles. On the other side of the room.

Tutor. The eye E will represent that situation:—the rays from the external parts of the arrow, A and B, flow convergingly along A *a* and B *b*, and if no glass were in the way they would meet at P; but the glass reflects the ray A *a* along *a* E, and the ray B *b* along *b* E; and as we always transfer the image of an object in that direction in which the rays approach the eye, we see the image of A along the line E *a* behind the glass, and the image of B along E *b*, and, of course, the image of the whole arrow is at R.

By means of a similar diagram, I will show you more clearly the principle of the *concave* mirror. Suppose an object *e* (Plate III. Fig. 20.) to be beyond the focus, F, and the spectator to stand at Z, the rays *e b* and *e d* are reflected, and where they meet in E the spectator will see the image.

James. That is between himself and the object.

Tutor. He must, however, be far enough from it to receive the rays after they have diverged from E, because every enlightened point of an object becomes visible only by means of a cône of diverging rays from it, and we cease to see it if the rays become parallel or converging.

Charles. Is the image inverted?

Tutor. Certainly, because the rays have crossed before they reach the eye.

You may see this subject in another point of view: let *r y* (Plate III. Fig. 21.) be a concave mirror, and O the centre of concavity: divide O A equally in F, and take the half. the third, and the fourth, &c. of F O,

l mark these divisions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c. Let be extended, and parts be taken in it al to F O, at 2, 3, 4, &c. Now if any of points 1, 2, 3, 4, &c. be the focus of incit rays, the correspondent points 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, in O F will be the focus of the reflected s, and *vice versa.*

James. Do you mean by that, if incident s be at $\frac{1}{2}$ or $\frac{1}{3}$, or $\frac{1}{4}$, the reflected rays will at 2, 3, 4?

Tutor. I do: place a candle at 2, and an inrted image will be seen at $\frac{1}{2}$: now place it 4, and it will also move back to $\frac{1}{4}$: these ages may be taken on paper held in those spective places.

Charles. I see the farther you proceed e way with the candle, the nearer its inrted image comes to the point F.

Tutor. True: and it never gets beyond it, r that is the focus of parallel rays after rection, or of rays that come from an infite distance.

James. Suppose the candle were at O?

Tutor. Then the object and image will

coincide: and as the image of an object between F, and a concave speculum, is on the other side of the speculum, this experiment of the candle and paper cannot be made.

I will now just mention an experiment that we may hereafter make. At one end of an oblong box, about two feet long, and 15 inches wide, is to be placed a concave mirror; near the upper part of the opposite end a hole is made, and about the middle of the box is placed a hollow frame of pasteboard that confines the view of the mirror. The top of the box next the end in which the hold is made is covered with a glass but the other half is darkened. Under the hole are placed in succession different pictures, properly painted, which are thrown into perspective by the mirror, and produce a beautiful appearance.

CONVERSATION XIV.

Of Convex Reflection—Of Optical Delusions—Of Anamorphoses.

CHARLES. You cannot, I see, make the same experiment with the candle, and a convex mirror, that you made yesterday with the concave one.

Tutor. Certainly, because the image is formed behind the glass: but it may, perhaps, be worth our while to consider how the effect is produced in a mirror of this kind. Let *a b* (Plate III. Fig. 22.) represent a convex mirror, and A *f* be half the radius of convexity, and take A F, F O, O B, &c, each equal A *f*. If incident rays flow from

2, the reflected rays will appear to con
from behind the glass at $\frac{1}{2}$.

James. Do you mean if a candle be pl
ced at 2, the image of it will appear to
formed at $\frac{1}{2}$ behind the glass?

Tutor. I do: and if that, or any oth
object, be carried to 3, 4, &c. the ima
will also go backward to $\frac{1}{3}$, $\frac{1}{4}$, &c.

Charles. Then, as a person walks towar
a convex spherical reflector, the image a
pears to walk towards him, constantly i
creasing in magnitude, till they touch ea
other at the surface.

Tutor. You will observe that the ima
however distant the object, is never fartl
off than at *f*; that is, the imaginary focus
parallel rays.

James. The difference then betw
convex and concave reflectors is, that
point *f* in the *former* is behind the gl
and in the *latter* it is before the glass as

Tutor. Just so: from the property
diminishing objects, spherical reflectors

not only pleasing ornaments for our best rooms, but are much used by all lovers of picturesque scenery. "Small convex reflectors," says Dr. Gregory, "are made for the use of travellers, who, when fatigued by stretching the eye to Alps towering on Alps, can, by their mirror, bring these sublime objects into a narrow compass, and gratify the sight by pictures which the art of man in vain attempts to imitate."*

Concave mirrors have been used for many other and different purposes; for by them, with a little ingenuity, a thousand illusions may be practised on the ignorant and credulous.

Charles. I remember going with you to see an exhibition in Bondstreet, which you said depended on a concave mirror; I was desired to look into a glass, I did so, and started back, for I thought the point of a dagger would have been in my face. I look-

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* See Economy of Nature. Vol. I. p. 26. 2d Edition.

ed again, and a death's head snapped at me; and then I saw a most beautiful nosegay, which I wished to grasp, but it vanished in an instant.

Tutor. I will explain how these deceptions are managed: let E F (Plate III. Fig. 23.) be a concave mirror, 10 or 12 inches in diameter, placed in one room; A B the wain-scot that separates the spectator from it; but in this there is a square or circular opening which faces the mirror exactly. A nosegay, for instance, is inverted at C, which must be strongly illuminated by means of an Argand's lamp; but no direct light from the lamp is to fall on the mirror. Now a person standing at G will see an image of the nosegay at D.

James. What is to make it vanish?

Tutor. In exhibitions of this kind there is always a person behind the wainscot in league with the man that attends the spectator, who removes the real nosegay upon some hint understood between them.

harles. Was it then upon the man be- the scene that the approaching sword, the advancing death's head, &c. de- ed?

tor. It was: and persons have under- to exhibit the ghosts of the dead by ivances of this kind: for if a drawing : deceased be placed instead of the ay, it may be done. But such exhibi- are not to be recommended, and in- ought never to be practised, without ning the whole process to the astonish- :ctator afterwards.

ı large concave mirror be placed be- blazing fire so as to reflect the image fire on the flap of a bright mahogany a spectator suddenly introduced in om will suppose the fire to be on the

two large concave mirrors A and B : III. Fig. 24.) be placed opposite each , at the distance of several feet, and red *iarcoal be put in the focus* D, and some *wder in the other focus* C, it will pre-

sently take fire. The use of a pair of bellows may be necessary to make the charcoal burn strongly.—

This experiment may be varied by placing a thermometer in one focus, and lighted charcoal in the other, and it will be seen that the quicksilver in the thermometer will rise as the fire increases, though another thermometer at the same distance from the fire, but not in the focus of the glass, will not be affected by it.

James. I have seen concave glases in which my face has been rendered as long as my arm, or as broad as my body, how are these made?

Tutor. These images are called *anamorphoses*, and are produced from *cylindrical* conçave mirrors; and as the mirror is placed either *upright*, or on its *side*, the image of the picture is distorted into a very long or very broad image.

Reflecting surfaces may be made of various shapes, and if a regular figure be placed before an irregular reflector, the image will

:formed, but if an object, as a picture,
ıinted deformed, according to certain
, the image will appear regular. Such
:s and reflectors are sold by opticians,
hey serve to astonish those who are ig-
ıt of these subjects.

CONVERSATION XV.

Of the different Parts of the Eye.

CHARLES. Will you now describe the nature and construction of the telescope?

Tutor. I think it will be better first to explain the several parts of the eye, and the nature of vision in the simple state, before we treat of those instruments which are designed to assist it.

James. I once saw a bullock's eye dissected, and was told that it imitated a human eye in its several parts.

Tutor. The eye, when taken from the socket, is of a globular form, and it is com-

posed of three coats or skins, and three other substances called humours. This figure (Plate III. Fig 25.) represents the section of an eye, that is, an eye cut down the middle; and Fig. 26, the front view of an eye as it appears in the head.

Charles. Have these coats and humours all different names?

Tutor. Yes: the external coat, which is represented by the outer circle A B C D E, is called the *sclerotica;* the front part of this, namely, C *x* D, is perfectly transparent, and is called the *cornea;* beyond this, towards B and E, it is white, and called the white of the eye. The next coat, which is represented by the second circle, is called the *choroides.*

James. This circle does not go all round.

Tutor. No: the vacant space *a b* is that which we call the pupil, and through this alone the light is allowed to enter the eye.

Charles. What do you call that part, which is of a beautiful blue in some persons, as in cousin Lydia; and in others brown, or almost black?

Tutor. That, as *a c*, *b e*, is part
roides, and is called the *iris*.

Charles. The iris is sometime
ger than it is at another.

Tutor. It is composed of a
work, which contracts or expand
to the force of the light in
placed. Let James stand in a dar
two or three minutes:—now look

Charles. The *iris* of each is
and the pupil large.

Tutor. Now let him look stea
close to the candle.

Charles. The iris is considerab
and the pupil of the eye is but a
in comparison of what it was be

Tutor. Did you never feel
sitting some time in the dark, wh
were suddenly brought into the

James. Yes: I remember last
ing we had been sitting half an
in the dark at Mr. W——'s, an
dles were introduced, every one
pany complained of the pain wh
den light occasioned.

Tutor. By sitting so long in the dark, the iris was contracted very much, of course the pupil being large, more light was admitted than it could well bear, and therefore till time was allowed for the iris to adjust itself, the uneasiness would be felt.

Charles. What do you call the third coat, which, from the figure, appears to be still less than the choroides?

Tutor. It is called the *retina*, or net-work, which serves to receive the images of objects produced by the refraction of the different humours of the eye, and painted, as it were, on the surface.

Charles. Are the humours of the eye intended for refracting the rays of light, in the same manner as glass lenses?

Tutor. They are; and they are called the *vitreous*, the *crystalline*, and the *aqueous* humours. The *vitreous* humour fills up all the space z z, at the back of the eye; it is nearly of the substance of melted glass. The *crystalline* is represented by *d f*, in the shape of a double convex lens: and the *aqueous*,

or watery humour, fills up all that part of the eye between the crystalline humour, and the corner C x D.

James. What does the part A at the back of the eye represent?

Tutor. It is the optic nerve, which serves to convey to the brain the sensations produced on the retina.

Charles. Does the retina extend to the brain?

Tutor. It does: and we shall, when we meet next, endeavour to explain the office of these humours in effecting vision. In the mean time, I would request you to consider again what I have told you of the different parts of the eye; and examine, at the same time, both figures; viz. 25 and 26.

James. We will: but you have said nothing about the uses of the eye-brows and eye-lashes.

Tutor. I intended to have reserved this to another opportunity: but I may now say, that the eye-brows defend the eye from too strong a light; and they prevent the ey

from injuries by the sliding of substances down the forehead into them.

The eye-lids act like curtains to cover and protect the eyes during sleep: when we are awake, they diffuse a fluid over the eye, which keeps it clean and well adapted for transmitting the rays of light.

The eye-lashes, in a thousand instances, guard the eye from danger, and protect it from floating dust with which the atmosphere abounds.

CONVERSATION XVI.

E Manner of Vision.

CHARLES. I do not understand w
you meant when you said, the optic ne
served to convey to the brain the sensati
produced on the retina.

Tutor. Nor do I pretend to tell you
what manner the image of any object pain
on the retina of the eye is calculated to c
vey to the mind an idea of that object :
I wish to show you, that the images of
various objects which you see are pain
on the retina. Here is a bullock's eye, fr
the back part of which I cut away the th

coats, but so as to leave the vitreous humour perfect: I will now put against the vitreous humour a piece of white paper, and hold the eye towards the window; what do you see?

James. The figure of the window is drawn upon the paper; but it is inverted.

Tutor. Open the window, and you will see the trees in the garden drawn upon it in the same inverted state, or any other bright object that is presented to it.

Charles. Does the paper, in this instance, represent the innermost coat called the retina?

Tutor. It does; and I have made use of paper because it is easily seen through, whereas the retina is opake; transparency would be of no advantage to it. The retina, by means of the optic nerve, is conveyed to the brain, or, in other words, the optic nerve is an extension of the retina.

James. And does it carry the news of every object that is painted on the retina?

Tutor. So it should seem; for we have

an idea of whatever is drawn upon it. I direct my eyes to you, and the image of your person is painted on the retina of my eye, and I say I see you. So of any thing else.

Charles. You said the rays of light proceeding from external objects were refracted in passing through the different humours of the eye.

Tutor. They are, and converged to a point, or there would be no distinct picture drawn on the retina, and of course no distinct idea conveyed to the mind. I will show you what I mean by a figure, taking an arrow again as an illustration.

As every point of an object A B C (Plate IV. Fig. 27.) sends out rays in all directions, some rays from each point on the side next the eye, will fall upon the cornea between *x y*, and by passing through the humours of the eye they will be converged and brought to as many points on the retina, and will form on it a distinct inverted picture *c b a* of the object.

James. This is done in the same manner as you showed us by means of a double convex lens.

Tutor. All three of the humours have some effect in refracting the rays of light, but the crystalline is the most powerful, and that is a complete double convex lens: and you see the rays from A are brought to a point at *a*; those from B will be converged at *b*, and those from C at *c*, and, of course, the intermediate ones between A and B, B and C will be formed between *a* and *b*, and *b* and *c*. Hence the object becomes visible by means of the image of it being drawn on the retina.

Charles. Since the image is inverted on the retina, how is it that we see things in the proper position?

Tutor. This is a proper question, but one that is not very readily answered. It is well known that the sense of touch or feeling very much assists the sense of sight; some paintings are so exquisitely finished, and so much resemble sculpture, that the eye

is completely deceived, we then naturally extend the hand to aid the sense of seeing. Children who have to learn the use of all their senses, make use of their hands in every thing; they see nothing which they do not wish to handle, and therefore it is not improbable, that by the sense of the touch, they learn, unawares, to rectify that of seeing. The image of a chair, or table, or other object, is painted in an inverted position on the retina; they feel and handle it, and find it erect; the same result perpetually recurs, so that, at length, long before they can reason on the subject, or even describe their feelings by speech, the inverted image gives them an idea of an erect object.

Charles. I can easily conceive that this would be the case with common objects, such as are seen every day and hour. But will there be no difficulty in supposing that the same must happen with regard to any thing which I had never seen before? I never saw ships sailing on the sea till with-

in this month; but when I first saw them, they did not appear to me in an inverted position.

Tutor. But you have seen water and land before, and they appear to you, by habit and experience, to be lowermost, though they are painted on the eye in a different position: and the bottom of the ship is next the water, and consequently, as you refer the water to the bottom, so you must the hull of the ship which is connected with it. In the same manner all the parts of a distant prospect are right with respect to each other; and therefore, though there may be a hundred objects in the landscape entirely new to you, yet as they all bear a relation to one another, and to the earth on which they are, you refer them, by experience, to an erect position.

James. How is it that in so small a space as the retina of the eye, the images of so many objects can be formed?

Tutor. Dr. Paley* tells us,
pect from Hampstead Hill is
into the compass of a sixpe
cumstantially represented. A
travelling at its ordinary rate,
hour, passes in the eye only ov
part of an inch, yet the chang
distinctly perceived througho
progress." Now what he assert
is true: go to the window, ar
dily at the prospect before you,
many objects you can discern
ving your eye.

James. I can see a great
distinctly indeed, besides whi
cern others, on both sides, w
clearly defined.

Charles. I have another d
have two eyes, on both of wh
ges of objects are painted, h
we do not see every object do

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* See Paley's Natural Theology,
edition, or p. 13, in the Analysis of t
Author of these Dialogues.

Tutor. When an object is seen distinctly with both eyes, the *axes* of them are directed to it, and the object appears single ; for the optic nerves are so framed, that the correspondent parts, in both eyes, lead to the same place in the brain, and excite but one sensation. But if the axes of both eyes are not directed to the object, that object seems double.

James. How does that appear?

Tutor. Look at your brother, while I push your right eye out of its place towards the left.

James. I see two brothers, the one receding to the left hand of the other.

Tutor. The reason is this ; by pushing the eye out of its natural place, the pictures in the two eyes do not fall upon correspondent parts of the retina, and therefore the sensations from each eye are excited in different parts of the brain.

CONVERSATION XVII.

Of Spectacles, and of their Uses.

CHARLES. Why do people wear spectacles?

Tutor. To assist the sight, which may be defective from various causes. Some eyes are too flat, others are too convex: in some the humours lose a part of their transparency, and on that account, a deal of light that enters the eye is stopt and lost in the passage, and every object appears dim. The eye, without light, would be a useless machine. Spectacles are intended to collect the light, or to bring it to a proper degree of convergency.

Charles. Are spectacle-glasses always convex?

Tutor. No: they are convex when the eyes are too flat; but if the eyes are already very convex, then concave glasses are used. You know the properties of a convex glass?

James. Yes; it is to make the rays of light converge sooner than they would without.

Tutor. Suppose then a person is unable to see objects distinctly, owing to the cornea C D (Plate IV. Fig. 28.,) or to the crystalline *a b*, or both, being too flat. The focus of rays proceeding from any object, *x*, will not be on the retina, where it ought to be, but at *z* beyond it.

Charles. How can it be beyond the eye?

Tutor. It would be beyond it, if there were any thing to receive it; as it is, the rays flowing from *x*, will not unite at *d*, so as to render vision distinct. To remedy this, a convex glass *m n* is placed between the object and the eye, by means of which

the rays are brought to a focus
the image is formed at *d*.

James. Now I see the reas
ple are obliged, sometimes, to
many pairs of spectacles bef
those that will suit them. Th
exactly what degree of conve
sary to bring the focus just to

Tutor. That is right; for
the eye may vary as much as
countenance; of course, a pair
that might suit you, would no
to another, whose eyes should
milar aid.—What is the propert
glasses?

Charles. They cause the ra
diverge.

Tutor. Then for very roun
lar eyes, these will be useful, b
cornea C D, or crystalline *a b* (P
29.) be too convex, the rays flo
will unite into a focus before t
the retina, as at *z*.

Charles. If the sight then de
sations produced on the retina

not see the object at all, because the
f it does not reach the retina.

. True : but at z the rays cross one and pass on to the retina, where l produce some sensations, but not distinct vision, because they are ight to a focus there. To remedy concave glass *m n* is interposed be- ie object and the eye, which causes coming to the eye to *diverge;* and iore divergent when they enter the requires a very convex cornea or ne to bring them to a focus at the

:s. I have seen old people, when ng an object, hold it a good distance eir eyes.

r. Because there eyes being too flat, is is thrown beyond the eye, and e they hold the object at a distance the focus z (Fig. 28.) to the retain.

es. Very short-sighted people bring close to their eyes.

r. Yes, I once knew a young man is apt, in looking at his paper, to rub

out with his nose what he had written wit[h] his pen. In this case, bringing the objec[t] near the eye produces a similar effect to tha[t] produced by concave glasses: because th[e] nearer the object is brought to the eye, th[e] greater is the angle under which it is seen[:] that is, the extreme rays, and, of course, al[l] the others, are made more divergent.

James. I do not understand this.

Tutor. Well, let E be the eye, (Plate IV. Fig. 30.) and the object *a b* seen at *z*, and also at *x*, double the distance; will not the same object appear under different angles to an eye so situated?

James. Yes, certainly *a* E *b* will be larger than *c* E *d*, and will include it.

Tutor. Then the object being brought very near the eye, has the same effect as magnifying the object, or of causing the rays to diverge; that is, though *a b* and *c d* are of the same lengths, yet *a b* being nearest to the eye, will appear the largest.

Charles. You say the eyes of old people become flat by age, is th at the natural progress?

Tutor. It is; and therefore people who are very short-sighted while young, will probably see well when they grow old.

James. That is an advantage denied to common eyes.

Tutor. But people blessed with common sight, should be thankful for the benefit they derived while young.

Charles. And I am sure we cannot too highly estimate the science of optics, that has afforded such assistance to defective eyes, which, in many circumstances of life, would be useless without them.

CONVERSATION XVI

Of the Rainbow.

TUTOR. You have frequen
rainbow?

Charles. Oh, yes, and very o
are two at the same time, one
other; the lower one is by far the
liant.

Tutor. This is, perhaps, the n
tiful meteor in nature; it never
appearance but when a spectator
between the sun and the shower.
described by Thomson:

—Reflected from yon eastern cloud,
Bestriding earth, the grand ethereal bow
Shoots up immense; and every hue unfolds,
In fair proportion, running from the red
To where the vi'let fades into the sky.
Here, awful Newton, the dissolving clouds
Form, fronting on the sun, thy show'ry prism;
And to the sage-instructed eye unfold
The various twine of light, by thee disclos'd
From the white mingling maze.

James. Is a rainbow occasioned by the falling drops of rain?

Tutor. Yes, it depends on the reflection and refraction of the rays of the sun by the falling drops.

Charles. I know now how the rays of the sun are *refracted* by water, but are they *reflected* by it also?

Tutor. Yes; water, like glass, reflects some rays, while it transmits or refracts thers. *You know the* beauty of the rainw *consists in its* colours.

James. Yes, "the colours of the rai bow" is a very common expression; I ha been told there are seven of them, but it seldom that so many can be clearly disti guished.

Tutor. Perhaps that is owing to yc want of patience; I will show you the (lours first by means of the prism. If a r of light S (Plate v. Fig. 31.) be admitt into a darkened room, through a small h in the shutter $x\ y$, its natural course is alo the line to d; but if a glass prism $a\ c$ be troduced, the whole ray will be bent upwar and if it be taken on any white surface M N, it will form an oblong image P T, t breadth of which is equal to the diameter the hole in the shutter.

Charles. This oblong is of different (lours in different parts.

Tutor. These are the colours of t rainbow, which are described by Dr. D win as *untwisted:*

> Next with illumin'd hands through prisms brig
> Pleas'd they untwist the sevenfold threads of lig

Or, bent in pencils by the lens, convey
To one bright point the silver hairs of day.

James. But how is the light which is admitted by a *circular* hole in the window spread out into an oblong?

Tutor. If the ray were of one substance, it would be equally bent upwards, and make only a small circular image. Since, therefore, the image or picture is oblong, it is inferred that it is formed of rays differently refrangible, some of which are turned more out of the way, or more upwards than others; those which go to the upper part of the spectrum being most refrangible, those which go to the lowest part are the least refrangible, the intermediate ones possess more or less refrangibility, according as they are painted on the spectrum. Do you see the seven colours?

Charles. Yes, here is the *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, and *red*.

Tutor. These colours will be still more beautiful if a convex lens be interposed, at

These, when the clouds distil the rosy shower,
Shine out distinct adown the *watery bow*;
While o'er our heads the dewy vision bends
Delightful, melting on the fields beneath.
Myriads of mingling dies from these result,
And myriads still remain; infinite source
Of beauty, ever blushing, ever new.

Charles. You have not explained the principles of the upper or fainter bow.

Tutor. This is formed by two refractions and two reflections: suppose the ray T r, to be entering the drop B at r. It is refracted at r, reflected at s, reflected again at t, and refracted as it goes out at u, whence it proceeds, being separated, to the spectator at g. Here the colours are reversed? the angle formed by the red ray is 51°, and that formed by violet is 54°.

James. Does the same thing happen with regard to a whole shower, as you have shown with respect to the two drops?

Tutor. Certainly, and by the constant falling of the rain, the image is preserved constant and perfect. Here is the representation of the two bows. (Plate v. Fig. 33

he rays come in the direction S A, and the pectator stands at E with his back to the un, or, in other words, he must be between he sun and the shower.

This subject may be shown in another way; if a glass globule filled with water be hung sufficiently high before you, when the sun is behind, to appear red, let it descend gradually, and you will see in the descent all the other six colours follow one another. Artificial rainbows may be made with a common watering pot, but much better with a syringe fixed to an artificial fountain; and I have seen one by spirting up water from the mouth: it is often seen in cascades, in the foaming of the waves of the sea, in fountains, and even in the dew on the grass.

Dr. Langwith has described a rainbow, which he saw lying on the ground, the colours of which were almost as lively as those of the common rainbow. It was extended several hundred yards, and the colours were so strong, that it might have been seen much farther, if it had not been terminated by a bank, and the hedge of a field.

Rainbows have also been produced by the reflection of the sun's beams from a river: and Mr. Edwards describes one which must have been formed by the exhalations from the city of London, when the sun had been set twenty minutes.*

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* See P[illegible] Vols. VI. and L.

CONVERSATION XIX.

Of the Refracting Telescope.

UTOR. We now come to describe the :ture of telescopes, of which there are kinds; viz. the *refracting* and the *re- ng* telescope.

iarles. The former, or *refracting* tele- e, depends, I suppose, upon *lenses* for)peration; and the *reflecting* telescope chiefly by means of *mirrors*.

utor. These are the general principles ı which they are formed; and we shall)te this morning to the explanation of *'efracting* telescope. Here is one com- :ly fitted up.

James. It consists of two tubes, and two glasses.

Tutor. The tubes are intended to hold the glasses, and to confine the boundary of the view. I will therefore explain the principle by the following figure (Plate v. Fig. 34.) in which is represented the eye A B, the two lenses, *m n*, *o p*, and the object *x y*. The lens *o p*, which is nearest to the object, is called the object-glass, and that *m n* nearest to the eye is called the eye-glass.

Charles. Is the object-glass a double convex, and the eye-glass a double concave?

Tutor. It happens so in this particular instance, but it is not necessary that the eye-glass should be concave; the object-glass must, however, in all cases, be convex.

Charles. I see exactly, from the figure why the eye-glass is concave: for the convex lens converges the rays too quickly and the focus by that glass alone would be at E: and therefore the concave is put

near the eye to make the rays diverge so much as to throw them to the retina before they come to a focus.

Tutor. But that is not the only reason: by coming to a focus at E, the image is very small, in comparison of what it is when the image is formed on the retina, by means of the concave lens. Can you, James, explain the reason of all the lines which you see in the figure?

James. I think I can;—there are two pencils of rays flowing from the extremities of the arrow, which is the object to be viewed. The rays of the pencil flowing from *x*, go on diverging till they reach the convex lens *o p*, when they will be so refracted by passing through the glass, as to converge, and meet in the point *x*. Now the same may be said of the pencil of rays which come from *y*; and, of course, of all the pencils of rays flowing from the object between *x* and *y*. So that the image of the arrow would, by the convex lens, be formed at E.

Tutor. And what would happen if there were no other glass?

James. The rays would cross each other and be divergent, so that when they got to the retina, there would be no distinct image formed, but every point as *x* or *y*, would be spread over a large space, and the image would be confused. To prevent this, the concave lens *m n* is interposed; the pencil of rays which would, by the convex glass, converge at *x*, will now be made to diverge, so as not to come to a focus till they arrive at the retina: and the pencil of rays which would, by the convex glass, have come to a point at *y*, will, by the interposition of the concave lens, be made to diverge so much as to throw the focus of the rays to *b* instead of *y*. By this means, the image of the object is magnified.

Tutor. Can you tell the reason why the tubes require to be drawn out more or less for different persons?

Charles. The tubes are to be adjusted, in order to throw the focus of rays exactly

on the retina: and as some eyes are more convex than others, the length of the focus will vary in different persons, and, by sliding the tube up or down, this object is obtained.

Tutor. Refracting telescopes are used chiefly for viewing the terrestrial objects; two things, therefore, are requisite in them; the *first* is, that it should show objects in an upright position, that is, in the same position as we see them without glasses; and the second is, that they should afford a large *field of view.*

James. What do you mean, sir, by a field of view?

Tutor. All that part of landscape which may be seen at once, without moving the eye or instrument. Now in looking on the figure again, you will perceive that the concave lens throws a number of the rays beyond the pupil c of the eye, on to the iris on both sides, but those only are visible, or go to form an image, which pass through the pupil; and therefore, by a

telescope made in this way, the midd part of the object is only seen, or, in oth words, the prospect is by it very much d minished.

Charles. How is that remedied?

Tutor. By substituting a double conv eye-glass *g h* (Plate v. Fig. 35.) inste of the concave one. Here the focus the double convex lens is at E, and t glass *g h* must be so much more conv than *o p*, as that its focus may be also E: for then the rays flowing from the o ject *x y*, and passing through the obj glass *o p*, will form the inverted ima *m* E *d*. Now by interposing the dou convex *g h*, the image is thrown on retina, and it is seen under the large an D *e* C, that is, the image *m* E *d* will be m nified to the size C E D.

James. Is not the image of the objec the telescope inverted?

Tutor. Yes it is: for you see the ima on the retina stands in the same posit as the object; but we always see things

having the images inverted: and, therefore, whatever is seen by telescopes constructed as this is, will appear inverted to the spectator, which is a very unpleasant circumstance with regard to terrestrial objects it is on that account chiefly used for celestial observations.

Charles. Is there any rule for calculating the magnifying power of this telescope?

Tutor. It magnifies in proportion as the focal distance of the object-glass is greater than the focal distauce of the eye-glass. Thus, if the focal distance of the object-glass is ten inches, and that of the eye-glass only a single inch, the telescope magnifies the *diameter* of an object ten times: and the *whole suaface* of the object will be magnified a hundred times.

Charles. Will a small object, as a silver penny for instance, appear a hundred times larger through this telescope than it would by the naked eye?

Tutor. Telescopes, in general, represent terrestrial objects to be *nearer* and not *lar-*

N 2

ger: thus looking at the silver penny a hundred yards distant, it will not appear to be larger, but at the distance only of a single yard.

James. Is there no advantage gained, if the focal distance of the eye-glass, and of the object-glass, be equal?

Tutor. None; and therefore in telescopes of this kind we have only to increase the focal distance of the object-glass, and to diminish the focal distance of the eye-glass, to augment the magnifying power to almost any degree.

Charles. Can you carry this principle to any extent?

Tutor. Not altogether so: an object-glass of ten feet focal distance, will require an eye-glass whose focal distance is rather more than two inches and a half: and an object-glass with a focal distance of a hundred feet, must have an eye-glass whose focus must be about six inches from it. How much will each of these glasses magnify?

Charles. Ten feet divided by two inches and a half, give for a quotient forty-eight: and a hundred feet divided by six inches, give two hundred: so that the former magnifies 48 times, and the latter 200 times.

Tutor. Refracting telescopes for viewing terrestrial objects, in order to show them in their natural posture, are usually constructed with one object-glass, and three eye-glasses, the focal distances of these last being equal.

James. Do you make use of the same method in calculating the magnifying power of a telescope constructed in this way, as you did in the last?

Tutor. Yes; the three glasses next the eye having their focal distances equal, the magnifying power is found by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses. We have now said as much on the subject as is nesessary to our plan.

Charles. What is the construction of opera-glasses, that are so much used at the theatre?

Tutor. The opera glass is nothi[ng]
than a short refracting telescope.

The *night* telescope is only ab[out]
feet long; it represents objects i[n]
much enlightened, but not greatl[y magni]-
fied. It is used to discover obje[cts]
very distant, but which cannot othe[rwise be]
seen for want of sufficient light.

CONVERSATION XX.

Of Reflecting Telescopes.

TOR. This is a telescope of a dif-
t kind, and is called a *reflecting* tele-
.

arles. What advantages does the re-
ıg telescope possess over that which
lescribed yesterday?

tor. The great inconvenience attending
ting telescopes is their length, and on
account they are not very much used
high powers are required. A reflec-
f six feet long will magnify as much as
ractor of a hundred feet.

James. Are these, like the refracting telescopes, made in different ways?

Tutor. They were invented by Sir I. Newton, but have been greatly improved since his [illegible]me. The following figure (Plate VI. Fig. 36.) will lead to a description of one of those most [illegible]. You know that there is a great [illegible]y between *convex lenses* and *concave* [illegible].

Charles. They bot[illegible]m an inverted focal image of any rem[illegible]object, by the convergence of the pencil[illegible] rays.

Tutor. In instrument[illegible] the exhibitions of which are the effects of reflection, the concave mirror is substituted for the convex lens. T T (Fig. 36.) represents the large tube, and *t t* the small tube of the telescope, at one end of which is D F, a concave mirror, with a hole in the middle at P, the principal focus of which is at I K; opposite to the hole P is a small mirror L, concave towards the great one; it is fixed on a strong wire M, and may, by means of a long screw on the outside of the tube, be made to move

wards or forwards. A B is a remote
t; from which rays will flow to the
mirror D F.

mes. And I see you have taken only
rays of a pencil from the top, and two
the bottom.

utor. And in order to trace the pro-
of the reflections and refractions, the
r ones are represented by full lines, the
r ones by dotted lines. Now the rays
and E falling upon the mirror at D and
e reflected, and form an inverted image

arles. Is there any thing there to re-
the image?

utor. No: and therefore they go on
rds the reflector L, the rays from differ-
arts of the object crossing one another
le before they reach L.

mes. Does not the hole at P tend to
rt the image?

utor. Not at all; the only defect is,
there is less light. From the mirror L

the rays are reflected nearly parallel through P, there they have to pass the plano convex lens R, which causes them to converge at *a b*, and the [illegible]nage is now painted in the small tube near [illegible]e eye.

Charles. What is the other plano convex lens S for?

Tutor. [illegible] g[illegible]ns of the lens R, and the [illegible] conca[illegible]ors, brought the image of [illegible]ect s[illegible] as at *a b*, we only want to ma[illegible]ge.

James. This, I se[illegible] is done by the lens S.

Tutor. It is, and will appear as large as *c d*, that is, the image is seen under the angle *c f d*.

Charles. How do you estimate the magnifying power of the reflecting telescope?

Tutor. The rule is this: "Multiply the focal distance of the large mirror by the distance of the small mirror from the image *m*: then multiply the focal distance of the small mirror by the focal distance of the eye-glass; and divide these two products

one another, and the quotient is the magnifying power.

James. It is not likely that we should know all these in any instrument we possess.

Tutor. The following then is a method of finding the same thing by experiment. "Observe at what distance you can read any book with the naked eye, and then remove the book to the farthest distance at which you can distinctly read by means of the telescope, and divide the latter by the former."

Charles. Has not Dr. Herschel a very large reflecting telescope?

Tutor. He has made many, but the tube of the grand telescope is nearly 40 feet long, and 4 feet ten inches in diameter. The concave surface of the great mirror is 48 inches, of polished surface, in diameter, and it magnifies 6000 times. This noble instrument cost the Doctor four years' severe labour: it was finished August 28, 1789, on which

Tutor. You mean, that the letters appear, in that case, very much magnified, the reason of which is, that you are able to see at a much shorter distance in this way than you can without the intervention of the paper. Whatever instrument, or contrivance, can [illegible] minute objects visible and d[illegible]roperly a microscope.

James. If I l[illegible]ugh the hole in the paper at [illegible] of five or six inches from the print, it [illegible] not magnified.

Tutor. The object must be brought near to increase the angle by which it is seen; this is the principle of all microscopes, from the single lens to the most compound instrument. A (Plate VI. Fig. 37.) is an object not clearly visible at a less distance than A B; but if the same object be placed in the focus C (Fig. 38.) of the lens D, the rays which proceed from it will become parallel, by passing through the said lens, and therefore the object is distinctly visible to the eye at E,

placed any where before the lens. There are three distinctions in microscopes; the single, the compound, and the solar.

Charles. Does the single microscope consist only of a lens?

Tutor. By means of a lens a great number of rays proceeding from a point are united in the same sensible point, and as each ray carries with it the image of the point from whence it proceeded, all the rays united must form an image of the object.

James. Is the image *brighter* in proportion as there are more rays united?

Tutor. Certainly: and it is more distinct in proportion as their natural order is preserved. In other words, a single microscope or lens removes the confusion that accompanies objects when seen very near by the naked eye; and it magnifies the diameter of the object, in proportion as the focal distance is less than the limit of distinct vision, which we may reckon from about six to eight inches.

Charles. If the focal distance of a reading-glass be four inches, does it magnify the diameter of each letter only twice?

Tutor. Exactly so: but the lenses used in microscopes are often not more than $\frac{1}{4}$ or $\frac{1}{8}$ or even $\frac{1}{20}$ part of an inch radius.

James. And in a double convex the focal distance is always equal to the radius of convexity.

Tutor. Then tell me how much lenses of $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{20}$ of an inch will each magnify?

James. That is readily done; by dividing 8 inches, the limit of distinct vision, by $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{02}$.

Charles. And to divide a whole number, as 8, by a fraction, as $\frac{1}{4}$, &c. is to multiply the said number by the denominator of the fraction: of course, 8 multiplied by 4, gives 32; that is, the lens, whose radius is a $\frac{1}{4}$ of an inch, magnifies the diameter of the object 32 times.

James. Therefore the lenses of which

radii are $\frac{1}{8}$ and $\frac{1}{20}$ will magnify as 8 tiplied by 8, and 8 multiplied by 20; t is, the former will magnify sixty-four es, the latter 160 times, the diameter of object.

Tutor. You see then, that the smaller lens, the greater its magnifying power. . Hooke says, in his work on the micro-pe, that he has made lenses so small as be able, not only to distinguish the par-les of bodies a million times smaller than isible point, but even to make those visi of which a million times a million would dly be equal to the bulk of the smallest in of sand.

Charles. I wonder how he made them.

Tutor. I will give you his description: first took a very narrow and thin slip clear glass, melted it in the flame of a dle or lamp, and drew it out into ex-dingly fine threads. The end of one these threads he melted again in the ne till it run into a very small drop, ich, when cool, he fixed in a thin plate

of metal, so that the middle of it mig
directly over the centre of an extre
small hole made in the plate. Here
very convenient single microscope.

James. It does not seem, at first
so simple as those which you have just
described.

Tutor. A (Fig. 39.) is a circular
of brass, it may be made of wood, i
&c. in the middle of which is a very
hole, in this is fixed a small lens, the
distance of which is A D, at that dis
is a pair of pliers D E, which ma
adjusted by the sliding screw, and op
by means of two little studs *a e*;
these any small object may be taken
and viewed with the eye placed a
other focus of the lens at F, to which i
appear magnified as at I M.

Charles. I see by the joint it is ma
fold up.

Tutor. It is; and may be put in
case, and carried about in the pocket,
out any incumbrance or inconvenience

s now look at a double or compound microscope.

James. How many glasses are there in his?

Tutor. There are two; and the construction of it may be seen by this figure; *c d* (Fig. 40.) is called the object-glass, and *e f* the eye-glass. The small object *a b* is placed a little farther from the glass *c d* than its principal focus, so that the pencils of rays flowing from the different points of the object, and passing through the glass, may be made to converge and unite in as many points between *g* and *h*, where the image of the object will be formed. This image is viewed by the eye-glass *e f*, which is so placed that the image *g h* may be in the focus, and the eye at about an equal distance on the other side, the rays of each pencil will be parallel after going out of the eye-glass, as at *e* and *f*, till they come to the eye at , by the humours of which they will be converged and collected into points on

the retina, and form the large inverted image A B.

Charles. Pray, sir, how do you calculate the magnifying power of this microscope?

Tutor. There are two proportions which, when found, are to be multiplied into one another: (1.) As the distance of the image from the object-glass is *greater* than its distance from the eye-glass; and, (2.) as the distance from the object is *less* than the limit of distinct vision.*

Example. If the distance of the image from the object-glass be four times greater

* Dr. Vince gives the following rule for finding the linear magnifying power of a compound microscope: "It is equal to the least distance of distinct vision, multiplied by the distance of the image from the object-glass, divided by the distance of the object from the object-glass, multiplied by the focal *length* of the eye-glass."

than from the eye-glass, the magnifying power of four is gained; and if the focal distance of the eye-glass be one inch, and the distance of distinct vision be considered at seven inches, the magnifying power of seven is gained, and 7 multiplied by 4 gives 28; that is, the diameter of the object will be magnified twenty-eight times, and the surface will be magnified 784 times.

James. Do you mean that an object will, through such a microscope, appear 784 times larger than by the naked eye?

Tutor. Yes, I do; provided the limit of distinct vision be seven inches; but some persons who are short-sighted, can see as distinctly at five or four inches, as another can at seven or eight: to the former the object will not appear so large as to the latter.

Ex. 2. What will a microscope of this kind magnify to three different persons, whose eyes are so formed as to see distinctly at the distance of 6, 7, and 8 inches by the naked eye; supposing the image of the

course, the rays cross, and diverge t white screen on which the image of th ject will be painted.

Charles. I see the object is placed a behind the focus.

Tutor. If it were in the focus it woul burnt to pieces immediately. The mag ing power of this instrument depends o distance of the sheet or white screen; haps about 10 feet is as good a distan any. You perceive that the size of the age is to that of the object as the dist of the former from the lens n m, is to of the latter.

James. Then the nearer the o to the lens, and the farther the screen it, the greater the power of this m scope.

Tutor. You are right, and if the o be only half an inch from the lens, an screen nine feet, the image will be 46 times larger than the object: do you derstand this?

Charles. Yes, the object being only half an inch from the lens, and the image nine feet or one hundred and eight inches, or two hundred and sixteen half inches, the diameter of the image will be two hundred and sixteen times larger than the diameter of the object, and this number multiplied into itself will give 46,656.

Tutor. This instrument is calculated only to exhibit transparent objects, or such as the light can pass through in part. For opaque objects, a different microscope is used: and, indeed, there are an indefinite number of microscopes, and of them all, we may say, though in different degrees:

The artificial convex will reveal
The forms diminutive that each conceal;
Some so minute, that, to the one extreme,
The mite a vast Leviathan would seem;

That yet of organs, functions, sense partake
Equal with animals of larger make.
In curious limbs and cloathing they surpass
By far the comeliest of the bulky mass.
A world of beauties! that thro' all this frame
Creations grandest miracles proclaim.

BROWNE.

CONVERSATION XXII.

Of the Camera Obscura, Magic Lanthorn, and Multiplying Glass.

TUTOR. We shall now treat upon some miscellaneous subjets; of which the first shall be the *Camera Obscura.*

Charles. What is a camera obscura?

Tutor. The meaning of the term is a darkened chamber: the construction of it is very simple, and will be understood in a moment by you, who know the properties of the convex lens.

A convex lens placed in a hole of a window-shutter, will exhibit, on a white sheet of paper placed in the focus of the glass, all

the objects on the outside, as fields, men, houses, &c. in an inverted orde

James. Is the room to be quite except the light which is admitted thr the lens?

Tutor. It ought to be so; and, to i a very interesting picture, the sun sh shine upon the objects.

James. Is there no other kind of cam obscura?

Tutor. A portable one may be ma with a square box, in one side of which is t be fixed a tube, having a convex lens in it within the box is a plane mirror reclining back wards from the tube, in an angle of forty-fiv degrees.

Charles. On what does this mirror re flect the image of the object?

Tutor. The top of the box is a squar of unpolished glass, on which the picture i formed. And if a piece of oiled paper b stretched on the glass, a landscape may b *easily* copied; or the outline may be sketc on the rough surface of the glass.

James. Why is the mirror to be placed at an angle of 45 degrees exactly?

Tutor. The image of the objects would naturally be formed at the back of the box opposite to the lens; in order, therefore, to throw it on the top, the mirror must be so placed that the reflected ray shall be perpendicular to the incidental. In the box, according to its original make, the top is at right angles to the end, that is, at an angle of 90 degrees, therefore the mirror is put at half 90, or 45 degrees.

Charles. Now the incident rays falling upon a surface which declines to an angle of 45 degrees, will be reflected at an equal angle of 45 degrees, which is the angle that the glass top of the box bears with respect to the mirror.

James. If I understand you clearly, had the mirror been placed at the end of the box, or parallel to it, the rays would have been reflected back to the lens; and none would have proceeded to the top of the box.

Tutor. True: in the same manner as

when one person stands before a looking-glass, another at the side of the room cannot see his image in the glass, because the rays flowing from him to the looking-glass are thrown back to himself again; but let each person stand on the opposite side of the room, while the glass is in the middle of the end of it, they will both stand at an angle of 45 degrees, with regard to the glass, and rays from each will be reflected to the other.

Charles. Is the tube fixed in this machine?

Tutor. No; it is made to draw out, or push in, so as to adjust the distance of the convex glass from the mirror, in proportion to the distance of the outward objects, till they are distinctly painted on the horizontal glass.

James. Will you now explain the structure of the magic-lanthorn, which has long afforded us occasional amusement?

Tutor. This little machine consists, as you know, of a sort of tin box; within which is a lamp or candle, the light of this

asses through a great plano-convex lens, laced in a tube fixed in the front. This trongly illuminates the objects which are painted on slips of glass, and placed before the lens in an inverted position. A sheet, or other white surface, is placed to receive the images.

Charles. Do you invert the glasses on which the figures are drawn, in order that the images of them may be erect.

Tutor. Yes: and the illumination may be greatly increased, and the effect much more powerful, by placing a concave mirror at the back of the lamp.

Charles. Did you not tell us that the *Phantasmagoria*, which we saw at the Lyceum, was a species of the magic lanthorn?

Tutor, There is this difference between hem: in common magic lanthorns, the fiures are painted on transparent glass, conequently the image on the screen is a cirle of light, having a figure or figures on it; ut in the Phantasmagoria, all the glass is nade opaque, except the figure only, which

being painted in transparent colours light shines through it, and no ligh come upon the screen but what through the figure.

James. But there was no sheet ceive the picture.

Tutor. No; the representation was th on a thin screen of silk placed betwee spectators and the lanthorn.

Charles. What caused the images pear approaching and receding?

Tutor. It is owing to removing th thorn farther from the screen, or bri it nearer to it; for, the size of the must increase, as the lanthorn is c back, because the rays come in the sh a cone, and as no part of the screen is ble, the figure appears to be formed air, and to move farther off when it be smaller, and to come nearer as it inc in size.

James. Here is another instrumer construction of which you promised plain: the *multiplying glass.*

Tutor. One side of this glass is cut into many distinct surfaces, and in looking at an object, as your brother, through it, you will see not one object only, but as many as the glass contains plane surfaces.

I will draw a figure to illustrate this: Let (Plate VI. Fig. 42.) A *i* B represent a glass, flat at the side next the eye H, and cut into three distinct surfaces on the opposite side, as A *b*, *b* *d*, *d* B. The object C will not appear magnified, but as rays will flow from it to all parts of the glass, and each plane surface will refract these rays to the eye, the same object will appear to the eye in the direction of the rays, which enter it through each surface. Thus a ray C *i* falling perpendicularly on the middle surface, will suffer no refraction, but show the object in its true place at C: the ray from C *b* falling obliquely on the plane surface A *b*, will be refracted in the direction *b* *e*, and on leaving the glass at *e*, it will pass to the eye in the direction *e* H, and therefore it appears at E; and the ray C *d* will, for the same

reason, be refracted to the eye in the direction B H and the object C will appear also in D.

If, instead of three sides, the glass had been cut into 6 or 20, or any other number, there would have appeared 6, 20, &c. different obj[illegible] c[illegible] ated.

MAGNETISM

CONVERSATION XXIII.

Of the Magnet: its Properties; useful to Mariners, and others; Iron rendered Magnetic; Properties of the Magnet.

TUTOR. You see this dark-brown mineral body, it is almost black, and you know it has the property of attracting needles and other small iron substances.

James. Yes, it is called a load-stone, leading-stone, or magnet; we have often been amused with it: but you told us that it possessed a much more important property than that of attracting iron and steel.

Tutor. This is what is called the *directive property*, by which mariners are enabled

to conduct their vessels through t
ocean out of the sight of land:
of this, miners are guided in their
nean inquiries, and the travelle
deserts otherwise impassable.

Charles. Were not mariners
make long and very distant voyag
property of the magnet was disco

Tutor. Till then, they conten
selves with mere coasting voyage
trusting themselves from the sigh

James. How long is it since th
ty of the magnet was first known

Tutor. About five hundred y
it is not possible to ascertain, wit
gree of precision, to whom we are
for this great discovery.

Charles. You have not told u
the discovery consists.

Tutor. When a magnet, or a n
bed with a magnet, is freely susp
will always, and in all places, sta
north and south.

Charles. Is it known which end points to the north, and which the south?

Tutor. Yes: or it would be of little use: each magnet, and each needle, or other piece of iron, that is made an *artificial* magnet by being properly rubbed with the *nautral* magnet, has a north end and a south end, called the *north* and *south poles*: to the former a s mark placed, for the purpose of distinguishing it.

James. Then if a ship were to make a voyage to the north, it must follow the direction which the magnet takes.

Tutor. True; and if it were bound a westerly course, the needle always pointing north, the ship must keep in a direction at right angles to the needle. In other words, the direction of the needle must be across the *ship*.

Charles. Could not the same object be obtained by means of the pole star?

Tutor. It might, in a considerable degree, provided *you could* always ensure a fine lear *sky*; *but* what is to be done in cloudy

weather, which, in some latitudes, will last for many days together?

Charles, I did not think of that.

Tutor. Without the use of the magnet, no persons could have ventured upon such voyages as those to the East Indies, and other distant parts; the knowledge, therefore, of this instrument cannot be too highly prized.

James. Is that a magnet which is fixed to the bottom of the globe, and by means of which we set the globe in a proper direction with regard to the cardinal points, north, south, east, and west.

Tutor. That is called a compass, the needle of which being rubbed by the natural or real magnet, becomes possessed of the same properties as those which belong to the magnet itself.

Charles. Can any iron and steel be made magnetic?

Tutor. They may; but steel is the most proper for the purpose. Bars of iron thus prepared are called *artificial magnets*.

James. Will these soon lose the properties thus obtained?

Tutor. Artificial magnets will retain their properties almost any length of time, and since they may be rendered more powerful than natural ones, and can be made of any form, they are generally used, so that the natural magnet is kept as a curiosity.

Charles. What are the leading properties of the magnet?

Tutor. (1.) A magnet attracts iron. (2.) When placed so as to be at liberty to move in any direction, its north end points to the north pole, and its south end to the south pole: that is called the *polarity* of the magnet. (3.) When the *north* pole of one magnet is presented to the *south* pole of another, they will attract one another. But if the two *south*, or the two *north* poles, are presened to each other, they will repel. (4.) When a magnet is so situated as to be at liberty to move any way, the two poles of it do *not lie in an horizontal* direction, it inclines *one of its poles* towards the horizon, and

of cours elevates the other pole above it; this is called the *inclination* or *dipping* of the magnet. (5.) Any magnet may be made to impart its properties to iron and steel.

CONVERSATION XXIV.

Magnetic Attraction and Repulsion.

TUTOR. Having mentioned the several properties of the magnet or loadstone, I intend, at this time, to enter more particularly into the nature of magnetic attraction and repulsion.—Here is a thin iron bar, eight or nine inches long, rendered magnetic, and on that account it is now called an artificial magnet: I bring a small piece of iron within a little distance of one of the poles of the magnet, and you see it is attracted or drawn to it.

Charles. Will not the same effect be produced, if the iron be presented to any other *part of the magnet?*

Tutor. The attraction is strongest at [th]e poles, and it grows less and less in pro[po]rtion to the distance of any part fr[om th]

poles, so that in the middle, between the poles, there is no attraction, as you shall see by means of this large needle.

James. When you held the needle near the pole of the magnet, the magnet moved to that, which looks as if the needle attracted the magnet.

Tutor. You are right: the attraction is mutual, as is evident from the following experiment. I place this small magnet on a piece of cork, and the needle on another piece, and let them float on water, at a little distance from each other, and you observe that the magnet moves towards the iron, as much as the iron moves towards the magnet.

Charles. If two magnets were put in this situation, what would be produced?

Tutor. If poles of the same name, that is, the two north, or the two south, be brought near together, they will repel one another; but if a north and south pole be presented, the same kind of attaction will be visible, as there was between the magnet and needle.

James. Will there be any attraction or repulsion if other bodies, as paper, or thin slips of wood, be placed between the magnets, or between the magnet and iron?

Tutor. Neither the magnetic attraction nor repulsion is in the least diminished, or in any away affected by the interposition of any kind of bodies, except iron. Bring the magnets together within the attracting or repelling distance, and hold a slip of wood between them: you see they both come to the wood.

Charles. You said that iron was more easily rendered magnetic than steel, does it retain the properties as long too?

Tutor. If a piece of soft iron, and a piece of hard steel, be brought within the influence of a magnet, the iron will be most forcibly attracted, but it will almost instantly lose its acquired magnetism, whereas the hard steel will preserve it along time.

James. Is magnetic attraction and repulsion at all like what we have sometimes seen in electricity?

Tutor. In some instances there
similarity: Ex. I tie two pieces of
Plate VIII. Fig. 28.) each to a
thread which join at top, and let t
freely from a hook *x*. If I bring t
ed or north end of a magnetic bar j
them, you will see the wires repel
ther, as they are shown in the fig
ing from *z*.

Charles. Is that occasioned b
pelling power which both wires
quired in consequence of being bot
ed magnetic with the same pole?

Tutor. It is: and the same thi
have occurred if the south pole
presented instead of the north.

James. Will they remain long i
sition?

Tutor. If the wires are of very
they will quickly lose their magnet
but if steel wires be used, as comr
ing needles, they will continue to r
other, after the removal of the ma

Ex. II. I lay a sheet of pape
a table, and strew some iron fili

ɔw lay this small magnet Fig. 29.) among m, and give the table a few gentle knocks, as to shake the filings, and you observe in ıat manner they have ranged themselves out the magnet.

Charles. At the two ends or poles, the rticles of iron form themselves into lines, little sideways; they bend, and then form mplete arches, reaching from some point the northern half of the magnet to some her point in the southern half.—Pray how you account for this?

Tutor. Each of the particles of iron, by ing brought within the sphere of the magtic influence, becomes itself magnetic, and ssessed of two poles, and consequently sposes itself in the same manner as any her magnet would do, and also attracts th its extremities the contrary poles of ıer particles.

Ex. III. If I shake some iron filings rough a gauze sieve, upon a paper that vers a bar magnet, the filings will become ıgnets, and will be arranged in beautiful rves.

James. Does the polarity of the magnet reside only in two ends of its surface?

Tutor. No: one half of the magnet is possessed of one kind of polarity, and the other of the other kind; but the ends, or poles, are those points in which that power is the strongest.

Def. A line drawn from one pole to the other is called the axis of the magnet.

CONVERSATION XXV.

The Method of making Magnets—Of the Mariner's Compass.

TUTOR. I have already told you that artificial magnets, which are made of steel, are now generally used in preference to the real magnet, because they can be procured with greater ease, may be varied in their form more easily, and will communicate the magnetic virtue more powerfully.

Charles. How are they made?

Tutor. The *best* method of making artificial magnets is to apply one or more powerful magnets to pieces of hard steel,

taking care to apply the north pole c
magnet or magnets to that extremity
steel which is required to be made the
pole, and to apply the south pole c
magnet to the opposite extremity c
piece of steel.

James. Has a magnet, by commu
ing its properties to other bodies, its
power diminished?

Tutor. No, it is even increased
—A bar of iron, three or four feet
kept some time in a vertical pos
will become magnetic, the lower extr
of it attracting the south pole, an
pelling the north pole. But if the b
inverted, the polarity will be reversed

Charles. Will steel produce the
effects?

Tutor. It will not; the iron mu
soft, and hence bars of iron that have
long in a perpendicular position, are
rally found to be magnetical, as
irons, bars of windows, &c.—If a
piece of hard iron be made red hot

hen left to cool in the direction of the magnetical line, it usually becomes magnetical.

Striking an iron bar with a hammer, or rubbing it with a file, while held in this direction, renders it magnetical. An electric shock, and lightning, frequently render iron magnetic.

James. An artificial magnet you say is often more powerful than the real one; can a magnet, therefore, communicate to steel a stronger power than it possesses?

Tutor. Certainly not: but two or more magnets, joined together, may communicate a greater power to a piece of steel, than either of them possess singly.

Charles. Then you gain power according to the number of magnets made use of?

Tutor. Yes; very powerful magnets may be formed by first constructing several weak magnets, and then joining them together to form a compound one, and to act more powerfully upon a piece of steel.

The following methods ar
best for forming artificial mag
1. Place two magnetic
(Fig. 25.) in a line, so th
or marked end of one, shall
to the south end of the other
a distance, that the magne
touched, may rest with its m
the unmarked end of B, and i
end on the marked end of A.
the north end of the magne
south end of D, to the midd
opposite ends being elevated
gure. Draw L, and D asun
bar C, one towards A, the o
B, preserving the same elevat
L D, a foot or more from t
they are off the ends, then br
and south poles of these magn
and apply them again to the m
bar C as before: the same pro
repeated five or six times, t
bar, and touch the other thre
same way, and with care t
quire a strong fixed magnet

2. Upon a similar principle, two bars A B, C D (Fig. 26.) may be rendered magnetic. These are supported by two bars of iron, and they are so placed that the marked end B may be opposite to the unmarked end D; then place the two attracting poles G I, on the middle of A B, as in the figure moving them slowly over it ten or fifteen times. The same operation is to be performed on C D, having first changed the poles of the bars and then on the other faces of the bars; and the business is accomplished.

The touch thus communicated may be farther increased by rubbing the different faces of the bars with sets of magnetic bars, disposed as in Fig. 27.

James. I suppose all the bars should be very smooth.

Tutor. Yes, they should be well polished, the sides and ends made quite flat, and the angles quite square, or right angles.

There are many magnets made in the shape of horse-shoes, these are called horse-shoe magnets, and they retain their power

very long by taking care to joi
iron to the end as soon as it is
Charles. Does that prevent
from escaping?

Tutor. It should seem so;
of a magnet is even increased
a piece of iron to remain atta
or both of its poles. Of cou
magnet should always be thus l

James. How is magnetism
cated to compass needles?

Tutor. Fasten the needle
board, and draw magnets abou
long, in each hand, from the c
needle outwards; then raise th
considerable distance from the
bring them perpendicularly d
centre, and draw them over ag
peat this operation about twent
the ends of the needle will
poles contrary to those that to

Charles. I remember seein
when I was on board the fri
off Worthing, the needle was i
a glass over it.

Tutor. The mariner's compass consists of the box, the card or fly, and the needle. The box is circular, and is so suspended as to retain its horizontal position in all the motions of the ship. The glass is intended to prevent any motion of the card by the wind, the card or fly moves with the needle, which is very nicely balanced on a centre. It may, however, be noticed that a needle which is accurately balanced before it is magnetised, will lose its balance by being magnetised, on account of what is called the *dipping*, therefore a small weight, or moveable piece of brass, is placed on one side of the needle, by the shifting of which the needle will always be balanced.

CONVERSATION

Of the Variation of the Co

CHARLES. You said, I t
magnet pointed *nearly* north a
much does it differ from that l

Tutor. It rarely points exa
south, and the *deviation* fron
called the *variation of the co*
is said to be east or west.

James. Does this differ at di

Tutor. It does; and the
very different in different
world. The variation is not
that it was half a century ag
same now at London that it

Kamtschatka. The needle is continually traversing slowly towards the east and west.

This subject was first attended to by Mr. Burrows, about the year 1580, and he found the variation then, at London, about 11° 11′ east. In year 1657, the needle pointed due north and south: since which the variation has been gradually increasing towards the west, and in the year 1803, it was equal to something more than 24° west, and was then advancing towards the same quarter.

Charles. That is at the rate of something more than ten minutes each year.

Tutor. It is, but the annual variation is not regular; it is more one year than another. It is different in the several months, and even in the hours of the day.

James. Then if I want to set a globe due north and south, to point out the stars by, I must move it about, till the needle in the compass points to 24° west?

Tutor. Just so: and mariners, knowing this, are as well able to sail by the compass, as if it pointed due north.

Charles. You mentioned the property

which the needle had of *dipping*, after the magnetic fluid was communicated to it: is that always the same?

Tutor. It probably is, at the same place: it was discovered by Robert Norman, a compass-maker, in the year 1576, and he then found it [illegible] dip nearly 72°, and from many observat[illegible] made [illegible] Royal Society, it is found [illegible]

James. [illegible] in different places?

Tutor. [illegible] ear 1773, observations were made [illegible] ubject, in a voyage toward the north pole, and from these it appears that

In latitude 60°	18′	the dip was 75°	0′
70	45	77	52
80	12	81	52
80	27	82	2½

I will show you an experiment on this subject. Here is a magnetic bar, and a small dipping needle: if I carry the needle, suspended freely on a pivot, from one end of the magnetic bar to the other, it will, when directly over the south pole, settle

directly perpendicular to it, the north end being next to the south pole. As the needle is moved, the dip grows less and less, and when it comes to the magnetic centre, it will be parallel to the bar; afterwards the south end of the needle will dip, and when it comes directly over the north pole, it will be again perpendicular to the bar.

The following facts are deserving of recollection.

1. Iron is the only body capable of being affected by magnetism.

2. Every magnet has two opposite points called *poles*.

3. A magnet freely suspended arranges itself so that these poles point nearly north and south. This is called the *directive property*, or polarity of the magnet.

4. When two magnets approach each other, the poles of the *same names*, that is, both north, or both south, repel each other.

5. Poles of different names attract each other.

6. The loadstone is an iron oar naturally possessing magnetism.

7. Magnetism may be communica
iron and steel,

8. A steel needle rendered magnet
fitted up in a box, so as to move fr
any direction, constitutes the mariner'
pass.

Charles. I think there is a similar
tween electricity and magnetism.

Tutor. You are right; there is a
derable analogy, and a remarkable
ence also between magnetism and
city.

ELECTRICITY is of two sorts, p
and negative; bodies possessed of th
sort of electricity, repel each othe
those possessed of different sorts
each other.—In MAGNETISM, every
has two poles; poles of the same na
pel each other, and the contrary poles
each other.

In ELECTRICITY, when a body,
natural state, is brought near to one
electrified, it acquires a contrary elec
and becomes attracted by it.—In MA
ISM, when an iron substance is broug

one pole of a magnet, it acquires a contrary polarity, and become attracted by it.

One sort of electricity cannot be produced by itself. In like manner, no body can have only one magnetic pole.

The electric virtue may be retained by electrics, but it pervades conducting substances. The magnetic virtue is retained by iron, but it pervades all other bodies.

On the contrary: the magnetic power differs from the electric, as it does not affect the senses with light, smell, taste, or noise, as the electric does.

Magnets attract only iron, but the electric fluid attracts bodies of every sort.

The electric virtue resides on the surface of electrified bodies, but the magnetic is internal.

A magnet loses nothing of its power by magnetising bodies, but an electrified body loses part of its electricity by electrifying other bodies.

ELECTRICITY.

CONVERSATION XXVII.

INTRODUCTION.

The early History of Electricity.

TUTOR. If I rub pretty briskly with my hand this stick of sealing-wax, and then hold lt near any small light substances, as little pieces of paper, the wax will attract them; that is, if the wax be held within an inch or more of the paper, they will jump up, and adhere to it.

Charles. They do; and I think I have heard you call this the effects of electricity, but I do not know what electricity is.

Tutor. It is the case with this part of science as with many others, we know it only by the effects which it produces. As I have not hitherto, in these conversations, attempted to bewilder your minds with useless theories, neither shall I, in the present case, attempt to say what the electrical fluid is: its action is well known; it seems diffused over every portion of matter with which we are acquainted, and, by the use of proper methods, it is as easily collected from surrounding bodies as water is taken from a river.

James. I see no fluid attaching to the sealing-wax when you have rubbed it.

Tutor. You do not see the air which you breathe, and with which you are surrounded, yet we have shown you* that it is a fluid, and may be taken from any vessel, as certainly, though not with so much ease, as water may be poured from this glass. With the exercise of a small degree of patience, you shall

* See Vol. II.

see such experiments as will not fail to convince you that their is as certainly a fluid, which is called the electric fluid, as there are such fluids as water and air.

Charles. Water must have been known since the creation, and the existence of the air could not long remain a secret, but who discovered the electric fluid, which is not at all evident to the sense either of sight or feeling?

Tutor. Thales, who lived six centuries before the Christian æra, was the first who observed the electrical properties of amber, and he was so struck with the appearances, that he supposed it to be animated:

> Bright *amber* shines on his electric throne,
> And adds ethereal lustre to his own.
>
> DARWIN.

James. Does amber attract light bodies like sealing-wax?

Tutor. Yes, it does; and there are many other substances, as well as these, that have the same power. After Thales, the first person we read of that noticed this subject

was Theophrastus, who discovered that *tourmalin* has the power of attracting light bodies. It does not, however, appear that the subject, though very curious, excited much attention till about 200 years ago, when Dr. Gilbert, an English physician, examined a great variety of substances, with a view of ascertaining how far they might or might not be ranked among *electrics*.

Charles. What is meant by an *electric?*

Tutor. Any substance being excited or rubbed by the hand, or by a woollen cloth, or other means, and has the power of attracting light bodies, is called an *electric*.

James. Is not electricity accompanied with a peculiar kind of light, and with sparks?

Tutor. It is, of which we shall speak more at large hereafter: the celebrated Mr. Boyle is supposed to have been one of the first persons who got a glimpse of the electrical light, or who seems to have noticed it, by rubbing a diamond in the dark. But he little imagined, at that time, what astonishing effects would afterwards be produ

ced by the same power. Sir Isaac Newton was the first who observed that excited glass attracted light bodies on the side opposite to that on which it was rubbed.

Charles. How did he make the discovery?

Tutor. Having laid upon the table a round piece of glass, about two inches broad, in a brass ring, by which it was raised from table about the eighth of an inch, and then rubbing the glass, some little bits of paper which were under it were attracted by it, and moved very nimbly to and from the glass.

Charles. I remember standing by a glazier when he was cementing, that is, rubbing over some window-lights with oil, and cleaning it off with a stiff brush and whiting, and the little pieces of whiting, under the glass, kept continually leaping up and down, as the brush moved over the glass.

Tutor. That was, undoubtedly, an electrical appearance, but I do not remember having ever seen it noticed by any writer on electricity. A complete history of this

science is given by Dr. Priestly, wh
hereafter, afford you much entertainr
interesting instruction. To-morrow
enter into the practical part of the
and I doubt not that the experimen
part of science will be as intere
those in any other which you have b
dying. The electric light, exhibite
ferent forms; the various signs of a
and repulsion acting on all bodies; t
tric shock, and the explosion of the
will give you pleasure, and excite y
miration,

CONVERSATION XXVIII.

Electric Attraction and Repulsion—Of Electrics and Conductors.

TUTOR. You must for a little time, it is, till we exhibit before you experinents to prove it, take it for granted that earth, and all bodies with which we are quainted, contain a certain quantity of ceedingly elastic and penetrating fluid, ich philosophers call the electric fluid.

Charles. You say a certain quantity: is imited?

Tutor. Like other bodies, it undoubty has its limits; this glass will hold a tain quantity of water, but if I attempt pour into it more than that quantity, a

part will flow over. So it is with th
tric fluid: there is a certain quantity
belongs to all bodies, and this is
their natural quantity, and so long as
contains neither more nor less tha
quantity, no sensible effect is produc

James. Has this table electricity

Tutor. Yes, and so has the inkstan
every thing else in the room; and if
to take proper means to put more
than it now has, and you were to pu
knuckle to it, it would throw it out
shape of sparks.

James. I should like to see this

Charles. But what would happen
should take away some of its natural
tity?

Tutor. Why then, if you present
part of your body to the table, as
knuckle, a spark would go from you
table.

James. But, perhaps, Charles mig
have more than his natural share,
that case he could not spare any.

utor. True; but to provide for this, earth on which he stands would lend a little to make up for what he parted to the table.

mes. This must be an amusing study; ink I shall like it better than any of the rs.

utor. Take care that you do not pay he amusement before we have done. ere is a glass tube about eighteen inches , and perhaps an inch or more in diam- ; I rub it up and down quickly in my l, which is dry and warm, and now I present it to these fragments of paper, ad, and gold-leaf: you see they all e to it. That is called electrical *attrac-*

harles. They jump back again now, now they return to the glass.

utor. They are, in fact, alternately at- ed and repelled, and this will last se- l minutes if the glass be strongly ex- l. I will rub it again, present your kle to it in several parts one after an- r.

James. What is that snapping
wise something like the prickin

Tutor. The snapping is oc
little sparks which come from
your knuckle, and these give tl
of pain.

Let us go into a dark room,
the experiment.

Charles. The sparks are evi(
now, but I do not know where th
from.

Tutor. The air and every thi
the fluid which appears in th
sparks; and, whatever be the c
I do not attempt to explain, th(
the glass with the hand collects
air, and having now more thaı
share, it parts with it to you, o
to any body else that may be n
to receive it.

James. Will any other subst
the hand, excite the tube?

Tutor. Yes, many others, and t
science, are called the *rubbers;* a

tube, or whatever is capable of being thus excited, is called an *electric*.

Charles. Are not all sorts of solid substances capable of being excited?

Tutor. You may rub this poker, or the round ruler for ever, without obtaining an electric spark from them.

James. But you said one might get a spark from the mahogany table if it had more than its share.

Tutor. So I say you may have sparks from the poker, or ruler if they possess more than their common share of the electric fluid.

Charles. How do you distinguish between bodies that can be, and those that cannot be, excited?

Tutor. The *former*, as I have told you, are called *electrics*, as the glass tube; the *latter*, such as the poker, the ruler, your body, and a thousand other substances, are denominated *conductors*.

Charles. I should be glad to know the reason of the distinction, because I shall be more likely to remember it.

Tutor. That is right: when you held your knuckle to the glass tube, you had several sparks from the different parts of it: but if I, by any means, overcharged a conductor, as this poker, all the electricity will come away at a single spark, because the superabundant quantity flows instantaneously from every part to that point where it has an opportunity of getting away. I will illustrate this by an experiment. But first of all let me tell you, that all *electrics* are called also *non-conductors*.

James. Do you call the glass tube a *non-conductor* because it does not suffer the electric fluid to pass from one part of it to another?

Tutor. I do :—silk, if dry, is a con-conductor. With this skein of sewing-silk, I hang the poker or other metal substance A (Plate VII. Fig. 1.) to a hook in the cieling, so as to be about twelve inches from it; underneath, and near the extremity, are some small substances, as bits of paper, &c. I will excite the glass tube, and present it to the upper part of the poker.

Charles. They are all attracted but now you take away the glass they are quiet.

Tutor. It is evident that the electric fluid passed from one part of the tube through the poker, which is a conductor, to the paper, and attracted it :—if the glass be properly excited, you may take sparks from the poker.

James. Would not the same happen if another glass tube were placed in the stead of the poker?

Tutor. You shall try.—Now I have put the glass in the place of the poker, but let me excite the other tube as much as I will, no effect can be produced on the paper :—there are no signs of electrical attraction, which shows that the electric fluid will not pass through glass.

Charles. What would have happened if any conducting substance had been used, instead of silk, to suspend the iron poker?

Tutor. If I had suspended the poker with a moistened hempen string, the electric fluid would have all passed away through

that, and there would hav
very trifling) appearances
the end of the poker.

You may vary these expe
make yourselves perfect wi
distinction between electrics
Sealing-wax is an electric,
cited as well as a glass tube
duce similar effects. I will
of *electrics*, and another of
posed according to the ord
fection, beginning in each li
perfect of their class : thus
electric than amber, and go
ductor than silver :

TABLE.

RICS.	CONDUCTORS.
nds.	All the metals in the following order;
stones, the sparent the	Gold; silver;
	Copper; platina;
	Brass; iron;
	Tin; quicksilver;
ubstances.	Lead.
ids.	The semi-metals.*
on.	Metallic ores.*
substances,	Charcoal.
, wool, and	The fluids of an animal body.
ugar.	Water, especially salt water and other fluids, except oil.
te dry.	
etallic ox-	
	Ice, snow.
al and vege-	Most saline substances.
ances.	Earthy substances.
nes.	Smoke; steam, and even a vacuum.

other chemical terms, are explained and strated in a work just published, by the Scientific Dialogues, entitled "*Dialogues*' *&c.*

CONVERSATION XXIX

Of the Electrical Machine.

TUTOR. I will now explain to
construction of the electrical mach
show you how to use it.

Charles. For what purpose is it ı

Tutor Soon after the subject of t
tric fluid engaged the attention of
science, they began to contrive the
methods of collecting large quantiti
By rubbing this stick of sealing-wa
collect a small portion: if I excite
the glass tube, I get still more. Th
therefore, was, to find out a m
which the largest quantities can

ed, with as little trouble and expense as may be.

James. You get more electricity from the tube than from the sealing-wax, because it is five or six times as large : by increasing the size of thetube, you would increase the quantity of the electric fluid, I should think.

Tutor. That is a natural conclusion. But if you look to the table of electrics, which I made out yesterday, you will see that had the wax been as large as the glass tube, it would not have collected so much of the electric fluid, because, in its own nature, it is not so good an electric.

Charles. By the table, glass stands as the most perfect electric, but there are several substances between it and wax, all of which are, I believe, more perfect electrics than wax.

Tutor. They are : Electricians, therefore, had no hesitation as to the nature of the substance : they fixed on glass, which being easily melted and run, or blown into all sorts of forms, is, on that account, very *valuable.*

The most common form th
is that of a glass cylinder, fr
inches in diameter to ten or t
is one completely fitted up(Pla
the cylinder A B is about eigh
ameter, and twelve or fourte
this I turn round in the fran
the handle D C.

James. What is the piece
K for?

Tutor. The cylinder woul
without a rubber you know:
count you see the glass pill
being cemented into a piece
is made to screw into the
machine; on the pillar is a cus
is attached a piece of black si

Charles. And I perceive
made to press very hard agai

Tutor. This pressure, wh
der is turned round fast, acts
the rubbing of the tube by the
in a still more perfect manne
it round.

mes. Here is not much sign of elec-
y yet.

tor. No: the machine is complete,
t has no means of collecting the fluid
the surrounding bodies: for you see
ushion or rubber is fixed on a glass
, and glass will not conduct the electric

arles. Nevertheless it does, by turning
l, show some signs of attraction.

tor. Every body in nature with which
re acquainted possesses a portion of
luid, and therefore the signs which are
evident arise from the small quantity
n exists in the rubber itself, and the at-
here that immediately surrounds the
ine.

arles. Would the case be different if
ubber were fixed on a conducting sub-
e instead of glass?

tor. It would; but there is a much
method: I will attach one end of this
chain to the cushion at R, which being se-
feet long, lies on the table, or on the
and this you know is connected, by

means other objects, with the earth, which is he grand reservoir of the electric fluid. Now see the effect of turning round the cylinder: but I must make every part of it dry and rather warm, by rubbing it with a dry warm cloth.

James. It is indeed very powerful. What a crack s!

Tutor. low-shutters.

Charles. ance is very beautiful: th silk dart all round the cylinder.

Tutor. I will now bring to the cylinder the tin conductor L, which is also placed on a glass pillar, F N, fixed in the stand at F.

James. What are the points in the tin conductor for?

Tutor. They are intended to collect the fluid from the cylinder. I will turn the cylinder, and do you hold your knuckle within four or five inches of the conductor.

Charles. The painful sensations which these sparks occasion, prove that the electric fluid is a very powerful agent when collected in large quantities.

Tutor. To show you the nature of conducting-bodies, I will now throw another brass chain over the conductor, so that one end of it may lie on the floor. See now if you can get any sparks while I turn the machine.

James. No, I can get none, put my kuckle as near to it as I will.—Does it all run away by the chain?

Tutor. It does; a piece of brass or iron wire would do as well; and so would any conducting substance which touched the conductor with one end, and the floor with the other: your body would do as well as the chain. Place your hand on the conductor, while I turn round the cylinder: and let your brother bring his knuckle near the conductor.

Charles I can get no spark.

Tutor. It runs through James to the earth, and you see his body is a conductor as well as the chain. With a very little contrivance, I can take sparks from you or James, as well as you did from the conductor.

James. I should like to see how that is done.

Tutor. Here is a small stool, having a mahogany top and glass legs. If you stand on that, and put your hand on the conductor, the electricity will pass from the conductor to your body.

Charles. Will [illegible]ass legs prevent it from running fro[illegible] to the earth?

Tutor. They will [illegible]and therefore what he receives from the conductor, he will be ready to part with t[illegible]y of the surrounding bodies, or to you if you bring your hand near enough to any part of him.

James. The sparks are more painful in coming through my clothes, than when I received them on my bare hand.

Tutor. They are: you understand, I hope, the process.

Charles. By means of the chain trailing on the ground, the electric fluid is collected from the earth on the glass cylinder, which gives it through the points to the conductor from this it may be conveyed away again by means of other conductors.

tor. Whatever body is supported, or
nted from touching the earth, or com-
cating with it, by means of glass or
non-conducting substances, is said to
sulated. Thus a body suspended on a
ine is insulated, and so is any substance
stands on glass, or resin, or wax, provi-
hat these are in a dry state, for mois-
will conduct away the electric fluid
any charged body.

VERSATION XXX.

Iachine.

CHARLES. W that shining stuff which I saw you put to the rubber yesterday?

Tutor. It is called *amalgam:* the rubber, by itself, would produce but a slight excitation: its power, however, is greatly increased by laying upon it a little of this amalgam, which is made of quicksilver, zinc, and tinfoil, with a little tallow or mutton suet.

James. Is their any art required in using this amalgam?

Tutor. When the rubber and silk flap are very clean and dry, and in their place, then spread a little of the amalgam upon a piece

ither, and apply it to the upper part of lass cylinder, while it is revolving from by this means, particles of the amal- will be carried by the glass itself to the r part of the rubber, and will increase xcitation.

arles. I think I once saw a globe, in- of a cylinder, for an electrical machine.

tor. You might: globes were used e cylinders, but the latter are the most enient of the two. The most powerful rical machines are fitted with flat plates ass. In our experiments we shall be nt with the cylinder, which will an- every purpose of explaining the prin- s of the science.

mes. As I was able to conduct the ricity from the tin conductor to the nd, could I likewise act the part of the , by conducting the fluid from the earth e cushion?

tor. Undoubtedly: I will take off the , and now do you keep your hand on *ishion while I* turn the handle.

James. I see the machine works as well as when the chain was on the ground.

Tutor. Keep your present position, but stand on the stool with glass legs; by which means there is now all communication cut off between the cushion and the earth; in other words, the cushion is completely insulated, and can only take from you what electricity it can get from your body. Go, Charles, and shake hands with your brother.

Charles. It does not appear that the machine had taken all the electricity from him, for he gave me a smart spark.

Tutor. You are mistaken; he gave you nothing, but he took a spark from you.

Charles. I stood on the ground; I was not electrified: how then could I give him a spark?

Tutor. The machine had taken from James the electricity that was in his body and by standing on the stool, that is, by being insulated, he had no means of receivin any more from the earth, or any surround ing objects; the moment, therefore,

rought your hand near him, the electricity passed from you to him.

Charles. I certainly felt the spark, but whether it went out of, or entered into, my hand, I cannot tell: have I then less than my share now?

Tutor. No: what you gave to your brother was supplied immediately from the earth. Here is another glass-legged stool; do you stand on this, but at the distance of a foot or two from your brother, who still keeps his place. I take the electricity from him by turning the machine, and as he stands on the stool, he has now less than his share. But you have your natural share, because though you also are insulated, yet you are out of the influence of the machine; extend, therefore, your hand, and give him a part of the electric fluid that is in you.

Charles. I have given him a spark.

Tutor. And being yourself insulated, you have now less than your natural quantity, to supply which you shall have some from me: give me your hand. You draw back without my touching it!

Charles. I did, but it was near enough to get a strong spark from you.

Tutor. When a person has *less* electricity than his natural share, he is said to be electrified *minus*, or negatively: but if he has *more* than his natural share, he is said to be electrified *plus*. or positively.

James. Then before Charles gave me the spark, I was electrified minus; and when he had given it to me, he was minus till he received it from you.

Tutor. That is right. Suppose you stand on a stool and hold the rubber, and Charles stand on another stool, and touch the prime conductor L, while I turn the machine, which of you will be plus, and which minus, electrified?

James. I shall be minus, because I give to the rubber: and Charles will be plus, because he receives from the conductor what I gave to the rubber, and which is carried by the cylinder to the conductor.

Tutor. You then have less than your share, and your brother has more than he ought to have. Now if I get another glass-legged stool,

I can take from Charles what he has too much, and give it to you who have too little.

Charles. Is it necessary that you should be insulated for this purpose?

Tutor. By being insulated I may perhaps carry back to James the very electricity which passed from him to you. But if I stand on the ground, the quantity which I take from you will pass into the earth, because I cannot, unless I am insulated, retain more than my natural share.

James. And what is given by you to me is likewise instantaneously supplied by the earth.

Tutor. It is. Let us make another experiment to show that the electric fluid is taken from the earth. Here are some little balls (Plate VII. Fig. 3.) made of the pith of elder: they are put on thread, and being very light, are well adapted to our purpose.

While the chain is on the cushion, and I work the machine, do you bring the balls *near the conductor* by holding the thread at D.

James. They are attra
the two balls repel each
gure x.

Tutor. I ought to h
the upper part D of the li
means you know the bal
silk is a non-conductor.
from the cushion, and pu
tor, so as to hang on th
turn the machine. Will
ed now, if you hold them

James. No, they are r

Tutor. Take them to

Charles. They are attr
now by being brought ne
they were before, by bei
conductor.

Tutor. Yes, and you
sparks from the cushion
now from the conductor
must be evident that th
brought from the earth.

Some machines are fu
conductors, one of which
the cushion, the other suc

l. Turn the cylinder, and both con-
s will be electrified; but any body
is brought within the influence of
will be attracted by one of the con-
s, and repelled by the other: and if
ı or wire be made to connect the two
er, neither will exhibit any electric ap-
ces: they seem, therefore, to be in
te states; accordingly electricians say,
e conductor connected with the cushion
atively electrified, and the other is
ely electrified.

CONVERSATION XXXI.

Of Electrical Attraction and Repulsion.

JAMES. What is this large roll of s ing-wax for?

Tutor. As I mean to explain, this m ing, the principles of electrical attrac and repulsion, I have, besides the electr machine, brought out for use a roll of s ing wax, which is about fifteen in long, and an inch and a quarter in dia ter; and the long glass tube.

Charles. Are they not both electrics, capable of being excited?

Tutor. They are; but the electricity

duced by exciting them has different or contrary properties.

James. Are there two kinds of electrics then?

Tutor. We will show you an experiment before we attempt to give any theory.—I will excite the glass tube, and Charles shall excite the wax. Now do you bring the pith-balls, which are suspended on silk (Fig. 3.) to the tube. They are suddenly drawn to it, and now they are repelled from one another, and likewise from the tube, for you cannot easily make them touch it again:—but take them to the excited wax.

James. The wax attracts them very powerfully: now they fall together again, and appear in the same state as they were in before they were brought to the excited tube.

Tutor. Repeat the experiment again and again, because on this two different theories have been formed. One of which is, that there are two electricities, called

by some philosophers the *vitreous* tive electricity, and *resinous* or electricity.

Charles. Why are they called and *resinous?*

Tutor. The word vitreous is L signifies any *glassy* substance; word *resinous*, used to denote electricity produced by resins, v possesses different qualities from duced by glass.

James. Is it not natural to sup there are two electricities, since th wax attracts the very same bodies excited glass repels?

Tutor. It may be as easily e by supposing that every body, in ral state, possesses a certain qu the electric fluid, and if a part taken away, it endeavours to ge other bodies; or if more be thr it than its natural quantity, it yie dily to other bodies that come w fluence.

Charles. I do not understand this.

Tutor. If I excite this glass tube, the electricity which it exhibits is supposed to come from my hand; but if I excite the roll of wax in the same way, the effect is, according to this theory, that a part of the electric fluid naturally belonging to the wax, passes from it through my hand to the earth: and the wax being surrounded by the air, which, in its dry state, is a non-conductor, remains exhausted, and is ready to take sparks from any body that may be presented to it.

James. Can you distinguish that the sparks come from the glass to the hand; and, on the contrary, from the hand to the wax?

Tutor. No: the velocity with which the electric spark moves, renders it impossible to say what course it takes; but I shall show you other experiments which seem *to justify* this theory: and as Nature *always works by* the simplest means, it *seems more* consistent with her usual op

rations, that there should be one fluid rather than two, provided that known facts can be equally well accounted for, by one as by two.

Charles. Can you account for all the leading facts by either theory?

Tutor. Yes, we can.

You saw when the pith-balls were electrified, they repelled one another. It is a general principle in electricity that two bodies having more than their natural share of the electric fluid, will repel one another. But if one have more, and the other less, than its share, they will attract one another.

James. How is this shown?

Tutor. I will hold this ball, which is insulated, by a silk thread, to the conductor, and do you, Charles, do the same with the other. Let us now bring them together.

Charles. No, we cannot: they fly from one another.

·. I will hold mine to the insulated
, and you shall hold yours to
ductor while the machine is turn-
r I suspect they will attract one an-

s. They do indeed.

es. The reason is this; that the
and whatever is in contact with
with a portion of its electricity;
conductor, and the adjoining bodies
ore than their share; therefore,
applied to the cushion, being nega-
ectrified, will attract the one con-
vith the conductor, which is posi-
ectrified.

. Here is a tuft of feathers, which
in a small hole in the conductor:
what happens when I turn the cy-

. They all endeavour to avoid
ier, and stand erect, in a beauti-
ner. Let me take a spark from
luctor: now they fall down in a

Tutor. When I turned the wheel all had more than their share of the tric fluid, and therefore they repelle another, but the moment the elect was taken away, they fell into their ral position. A large plume of fea when electrified, grows beautifully t expanding its fibres in all directions they collapse when the electricity is off.

James. Could you make the hairs o head repel one another?

Tutor. Yes, that I can. Stand o glass-legged stool, and hold the chai hangs on the conductor, in your hand, I turn the machine.

Charles. Now your hairs stand end.

James. And I feel something like webs over my face.

Tutor. There are, however, no cob but that is the sensation which a pers ways experiences if he be highly electr

the pith-ball, Charles, near your bro-
face.

mes. It is attracted in the same
er as it was before with the conduc-

tor. Hence you may lay it down as
ıeral rule, that all light substances
ıg within the influence of an electri-
ody, are attracted by it whether it is
ified positively or negatively.

arles. Because they are attracted by
ositive electricity to receive some of
uperabundant quantity ; and by the
ive, to give away some that they
ss.

tor. Just so : and when they have
ed as much as they can contain, they
epelled by the electrified body. The
thing may be shown in various ways.
ng excited this glass tube, either by
ing it several times through my hand,
means of a piece of flannel, I will
it near this small feather. See how
ly it *jumps* to the glass.

es. It does, and sticks to it.

Tutor. You will observe, that af minute or two, it will have taken as i electricity from the tube as it can when it will suddenly be repelled, jump to the nearest conductor; upon v it will discharge the superabundant el city that it has acquired.

James. I see it is now going to the gr that being the nearest conductor.

Tutor. I will prevent it by holdin electrified tube between it and the You see how unwilling it is to come in contact with the tube: by pursui can drive it where I please without t ing it.

Charles. That is, because the glass the feather are both loaded with the electricity.

Tutor. Let the feather touch the gr or any other conductor, and you wi that it will jump to the tube as fast as before.

I will suspend this brass plate, wh about five inches in diameter, to the

ictor, and at the distance of three or four
ches below I will place some small fea-
ers, or bits of paper cut into the figures
men and women. They lie very quiet
present; observe their motions as soon
I turn the wheel.

James. They exhibit a pretty country
ance: they jump up to the top plate, and
ien down again.

Tutor. The same principle is evident
all these experiments. The upper plate
is more than its own share of the elec-
ic fluid, which attracts the little figures:
soon as they have received a portion of
, they go down to give it to the lower
ate; and so it will continue till the up-
er plate is discharged of its superabun-
int quantity.

I will take away the plates, and hang a
iain on the conductor, the end of which
iall lie in several folds in a glass tum-
er; if I turn the machine, the electric
iid will run through the chain, and will
ectrify the inside of the glass. This done,

I turn it quickly over eight or ten pith-balls, which lie on the table.

Charles. That is a very amusing how they jump about! They serve fetch the electricity from the glass, ar ry it to the table.

Tutor. If, instead of the lower plate, I hold in my hand a pane and very clean glass, by the corne paper figures or pith-balls will not because glass being a non-conductin stance, it has no power of carrying the superabundant electricity from th suspended from the conductor. B hold the glass flat in my hand, the will be attracted and repelled, which that the electric fluid will pass th thin glass.

Take now the following results, and mit them to your memory.

(1.) If two insulated pith-balls be b near the conductor, they will rep other.

(2.) If an insulated conducto

with the cushion, and two insulated
lls be electrified by it, they will re-
h other.

If one insulated ball be electrified
prime conductor, and another by the
tor connected with the cushion, they
tract each other.

If one ball be electrified by glass,
nother by wax, they will attract
ther.

If one ball be electrified by a
h, and another by a rough excited
ube, they will attract one another.

CONVERSATION XXXII.

Of Electrical Attraction and Repulsion.

TUTOR. I will show you another stance or two of the effects of electrical traction and repulsion.

This apparatus (Plate VII. Fig. 4.) sists of three bells suspended from a wire, the two outer ones by small chains; the middle bell, and the two clap x x, are suspended on silk. From the mid bell there is a chain n, which goes to table, or any other conducting substan The bells are now to be hung by c on conductor, and the electrical machine put in motion.

James. The clappers go from bell to bell, and make very pretty music: how do you explain this?

Tutor. The electric fluid runs down the chains *a* and *b* to the bells A B, these having more than their natural quantity, attract the clapper *x x* which take a portion from A and B, and carry it to the centre bell N, and this, by means of the chain, conveys it to the earth.

Charles. Would not the same effect be produced if the clappers were not suspended on silk?

Tutor. Certainly not: nor will it be produced if the chain be taken away from the bell N, because then there is no way left to carry off the electric fluid to the earth.

Another amusing experiment is thus shown. Let there be two wires placed exactly one above another, and parallel; the upper one must be suspended from the conductor, the other is to communicate with the table. A light image placed between these will, when the conductor is electrified, appear like a rope-dancer.

This piece of leaf brass is called the *electric fish*, one end is a sort of obtuse angle, the other is acute: if the large end be presented towards an electrified conductor, it will fix to it, and, from its wavering motion it will appear to be animated.

This property of attaction and repulsion has led to many inventions of instruments called electrometers.

James. Is not an electrometer a machine to measure the strength of the electricity?

Tutor. Yes; and this is one of the most simple (Plate VII. Fig. 5.,) and it depends entirely upon the repulsion which takes place between two bodies in a state of electrification. It consists of a light rod and a pith-ball, hanging parallel to the stem, but turning on the centre of a semicircle, so as to keep close to its graduated limb. This is to be placed in a hole *a* on the conductor L, and according as the conductor is more or less electrified, the ball will fly farther from the stem.

Charles. If the circular part be marked with degrees, you may ascertain, I suppose,

y accurately, the strength of any given ge.

tor. Yes, you may; but you see how the air carries away the electricity, it ely remains a single moment in the to which it was repelled. Two pith- may be suspended parallel to one ano- on silken threads, and applied to any of an electrical machine, and they will, eir repulsion, serve for an electrometer, ey will repel one another the more, as nachine acts more powerfully.

mes. Has this any advantage over the ?

tor. It serves to show whether the icity be negative or positive; for if it sitive, by applying an excited stick of g-wax, the threads will fall together ; but if it be negative, excited sealing- or resin, or sulphur, or even a rod of , the polish of which is taken off, will them recede farther.

e have now perhaps said enough re- ing electrical attraction and repulsion, st for the present; I wish you, how-

ever, to commit the following result your memory.

(1.) Bodies that are electrified *posit* repel each other.

(2.) Bodies that are electrified *negat* repel each other.

Charles. Do you mean, that if two b have either more or less of the electric than their natural share, they will repel other if brought sufficiently near?

Tutor. That is exactly what I mean

(3.) Bodies electrified by contrary ers; that is, two bodies, one having n and the other less, than its natural sl attract each other very strongly.

(4.) Bodies that are electrified at light substances which are not electrifie

These are facts which, I trust have made evident to your senses. To-mo we will decribe what is usually callec Leyden phial.

CONVERSATION XXXIII.

Of the Leyden Phial or Jar.

TUTOR. I will take away the wires and the ball from the conductor, and then remove the conductor an inch or two farther from the cylinder. If the machine acts strongly, bring an insulated pith-ball, that is, you know, one hanging on silk, to the end of the conductor, nearest to the glass cylinder.

Charles. It is immediately attracted.

Tutor. Carry it to the other end of the conductor, and see what happens.

Charles. It is attracted again; but I thought it would have been repelled.

Tutor. Then as the ball was electrified before, and is still *attracted*, you are sure that the electricity of the two ends of the conductor are of different names; that is, one is *plus*, and the other *minus*.

James. Which is the positive, and which is the negative end?

Tutor. That end of the conductor which is nearest to the cylinder, becomes possessed of an electricity different from that of the cylinder itself.

James Do you mean that if the cylinder is positively electrified, the end of the conductor next to it is electrified negatively?

Tutor. I do: and this you may see by holding an insulated pith-ball between them.

Charles. Yes, it is now very evident, for the ball fetches and carries as we have seen it before.

Tutor. What you have seen with regard to the conductor, is equally true with respect to non-conducting bodies. Here is a common glass tumbler: if I throw within

ide it a greater portion of electricity than ts natural share, and hold it in my hand, or place it on any conducting substance, as a table, a part of the electric fluid, that naturally belongs to the outside, will make its escape through my body, on the table.

Charles. Let me try this.

Tutor. But you must be careful that you do not break the glass.

Charles. I will hang the chain on the conductor, and let the other end lie on the bottom of the glass, and James will turn the machine.

Tutor. You must take care that the chain does not touch the edge of the glass, because when the electric fluid will, by that means, run from one side of it to the other, and spoil the experiment.

James. If I have turned the machine enough, take the chain out, and try the two sides with the insulated pith-ball.

Charles. What is this? Something has *pierced through* my arms and shoulders.

Tutor. That is a trifling electrical shock, which you might have avoided, if you had waited for my directions.

Charles. Indeed it was not trifling: I feel it now.

Tutor. This leads us to the Leyden phial: so called, because the discovery was first made at Leyden, in Holland, and by means of a phial or small bottle.

James. Was it found out in the same manner as Charles has just discoverd it?

Tutor. Nearly so. Mr. Cuneus, a Dutch philosopher, was holding a glass phial in his hand, about half filled with water, but the sides above the water, and the outside was quite dry, a wire also hung from the conductor of an electrical machine into the water.

James. Did that answer to the chain?

Tutor. Just so: and, like Charles, he was going to disengage the wire with one hand, as he held the bottle in the other, and was surprised and alarmed by a sudden shock in his arms, and through his breast, whi[ch] he had not the least expected.

Charles. I do not think there was any think to be alarmed at.

Tutor. The shock which he felt was, probably, something severer than that which you have just experienced: but the terror was evidently increased by its coming so completely unexpected.

When M. Muschenbroeck first felt the shock, which was by means of a thin glass bowl, and very slight, he wrote to M. Reaumur, that he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two whole days before he recovered from the effects of the blow.

Charles. Perhaps he meant the fright.

Tutor. Terror seems have been the effect of the shock: for he adds, "I would not take a second shock, for the whole kingdom of France."

Mr. Ninkler, an experimental philosopher, at Leipsic, describes the shock as having given him convulsions, a heaviness in his head, such as he should feel if a large stone were on it, and he had reason to dread a fever, to prevent which he put himself on a course

of cooling medicines. "Twice," sa
"it gave me a bleeding at the nose, to
I am not inclined: and my wife, whc
riosity surpassed her fears, receiv
shock twice, and found herself so
that she could scarcely walk. Never
in the course of a few days, she recei
other shock, which caused a bleedin
nose."

James. Is this called the Leyden

Tutor. It is. They are now made
manner (Plate VII. Fig. 6.) B A is
jar, both inside and out are cover
tin foil about three parts of the way
far as x.

Charles. Does the outside cover
swer to the hand, and the inside c
to the water?

Tutor. They do. The piece of w
placed on the top, merely to support t
wire and knob v, to the bottom of
hangs a chain that rests on the bo
the jar. I will now set the jar
situation that it shall be within tw

inches of the conductor, while I work the machine.

James. The sparks fly rapidly from the conductor to the knob *v*.

Tutor. By that means, the inside of the jar becomes charged with a superabundant quantity of electricity: and as it cannot contain this, without, at the same time, driving away an equal quantity from the outside, the inside is positively electrified, and the outside is negatively electrified. To restore to the equilibrium, I must make a communication between the outside and inside with some conducting substance. That is, I must make the same substance touch, at the same time, the outside tin foil, and that which is within, or, which is the same thing, another substance that does touch it.

Charles. The brass wire touches the inside: if I, therefore, with one hand touch the knob, and with the other the outside covering, will it be sufficient?

Tutor. It will: but I had rather you would not, because the shock will be more powerful than I should wish either myself

or you to experience. Here is a bras with two little balls or knobs *b s* scre it (Plate VII. Fig. 7.) I will bring them, as *s*, to the outside, and the ot to the ball *v* on the wire.

James. What a brilliant spark, an a loud noise!

Tutor. The electric fluid, that oc the light and the noise, ran from the of the jar through the wire to *s*, and itself over the ouside.

Charles. Would it have gone th my arms if I had put one hand to t side, and touched the wire commun with the inside, with the other?

Tutor. It would, and you may co that the shock would have been in p tion to the quantity of the fluid col The instrument I used may be called charging-rod, But here is a more co ent one (Plate VII. Fig. 8.:) the ha is solid glass, fastened into a brass s and the brass work is the same as only by turning on a joint the arms opened to any extent.

ames. Why is the handle glass?

Tutor. Because glass being a non-con-
:tor, the electric fluid passes through the
ıss work without affecting the hand;
ereas, with the other, a small sensation
s perceived while I discharged the jar.

Charles. Would the jar never discharge
:lf?

Tutor. Yes: by exposure to the air for
ne time, the charge of the jar will be si-
tly and gradually dissipated, for the su-
abundant electric fluid of the inside will
ape, by means of the air, to the outside
the jar.—But electricians make it a rule
rer to leave a jar in its charged state.

CONVERSATION XXXIV.

Of the Leyden Jar—Lane's discharging Electrometer, and the Electrical Battery.

CHARLES. In discharging the jar yesterday, I observed that when one of the discharging-rods touched the outside of the jar, the flash and report took place before the other end came in contact with the brass wire that communicates with the inside coating.

Tutor. Yes, it acts in the same manner as when you take a spark from the conductor; you do not, for that purpose, bring your knuckle close to the tin.

James. Sometimes, when the machine acts very powerfully, you may get the spark a the distance of several inches.

Tutor. By the same principle, the higher an electrical or Leyden jar is charged, the more easily, or at a greater distance, is it discharged.

Charles. From your experiments it does not seem that it will discharge at so great a distance as that in which a spark may be taken from the conductor.

Tutor. Very frequently a jar will discharge itself, after it has accumulated as much of the electrical fluid as it can contain; that is, the fluid which is thrown on the inside coating will make its way over the glass, though a non-conductor, on to the outside coating.

James. In a Leyden jar, after the first discharge, you always, I perceive, take another and smaller one.

Tutor. The tin foil on the jar not being a perfect conductor, the whole quantity of fluid will not pass at first from the inside to the out: what remains is called the *residuum*, and this, in a large jar, would give you a considerable shock; therefore, I advise *you always,* in discharging an electri-

cal jar, to take away the residuum before you venture to remove the apparatus. I will now describe an electrometer, which depends, for its action, on the principles we have been describing.

Charles. Do you mean upon the jars discharging before the outside and inside coating are actually brought into contact?

Tutor. I do. (Plate VII. Fig. 10.) The arm D is made of glass, and proceeds from a socket on the wire of the electrical jar F. To the top of the glass arm is cemented another brass socket E, through which a wire, with balls B and C at each end, will slide backwards and forwards.

James. So that it may be brought to any distance from the ball A, which is on the wire, connected with the inside of the jar?

Tutor. Just so. When the jar F is set either in contact, or very near the conductor, as is represented in the figure, and the ball B is set at the distance of the eighth of an inch from the ball A, let a wire C be fixed between the ball C and the outside coating of the jar. Then as soon as

chine is worked, the jar cannot be charged yond a certain point, for when the charge strong enough to pass from A to the ll B, the discharge will take place, and e electric fluid collected in the inside will ss through the wire C K to the outside ating.

Charles. If you remove the balls to a eater distance from one another, will a ronger charge be required before the fluid n pass from the inside of the jar to the ll B, of the electrometer?

Tutor. Certainly: and therefore the dis-arge will be much stronger. This ma-ine is called Lane's Discharging Elec-ometer, from the name of the person who vented it. It is very useful in applying e electric shock to medical purposes, as e shall see hereafter.

This box contains nine jars or Leyden hials; (Plate VIII. Fig 9.) the wires which oceed from the inside of each three of ese jars, are screwed or fastened to a com-on horizontal wire E, which is knobbed each extremity, and by means of the

wires r r, the inside coatings of 3 or 6, or the whole 9, may be connected.

James. Is it a common box in which the jars are placed?

Tutor. The inside of the box is lined with tin foil; sometimes very thin tin-plates are used, for the purpose of connecting more effectually the outside coatings of all the jars.

Charles. What is the hook c on one of the sides of the box for?

Tutor. To this hook is fastened a strong wire, which communicates with the inside lining of the box, and, of course, with the outside coating of the jars. And, as you see, to the hook a wire is also fastened, which connects it with one branch of the discharging rod.

James. Is there any particular art to be used in charging a battery?

Tutor. No: the best way is, to bring a chain, or piece of wire, from the conductor to one of the balls on the rods that rest upon the jars; and then set the machine in

k. The electric fluid passes from the luctor to the inside of all the jars, it is charged sufficiently high for the ose. Great caution, however, must sed when you come to make experiments a battery, for fear of an accident, either ourself, or to spectators.

harles. Would a shock from this be at-ed with any bad consequences ?

utor. Yes : very serious accidents may en from the electricity accumulated large battery, and even with a battery as is represented in the plate, which e of the smallest made ; a shock may iven, which, if passed through the head, ther vital parts of the body, may be ded with very mischievous effects.

ames. How do you know when the ery is properly charged ?

utor. The quadrant electrometer (Plate Fig. 5.) is the best guide, and this may xed either on the conductor, or upon of the rods of the battery. But if it is *on the* battery, the stem of it should

be of a good length, not less than twelve ‹ fifteen inches.

Charles. How high will the index sta when the battery is charged?

Tutor. It will seldom rise so high as 9C because a machine, under the most favo able circumstances, cannot charge a batte so high, in proportion, as a single jar. Y may reckon that a battery is well charg when the index rises as high as 60°, or b tween that and 70°.

James. Is there no danger of breaki the jars when the battery is very high charged?

Tutor. Yes, there is; and if one jar cracked, it is impossible to charge the othe till the broken one be removed. To preve accidents, it is recommended, not to di charge a battery through a good conduct except the circuit is at least five feet long

Charles. Do you mean the wire shou be so long?

Tutor. Yes, if you pass the char through that; but you may carry it thr any conductor.

Before a battery be used, the uncoated rt of the jars must be made perfectly an and dry, the smallest particles of dust ll carry away the electric fluid. And af- an explosion, always connect the wire m the hook, with the ball, to prevent y residuum from remaining.

CONVERSATION XXX\

Experiments made with the Electrical B

TUTOR. I will now show yc experiments with this large batte: perform these in perfect safety, I n you to stand a good distance from will prevent accidents.

Example 1. I take this quire of paper, and place it against the | wire that comes out of the box; ai the battery is charged I put one the discharging-rod to a knob of oı wires F, and bring the other that part of the paper that sta

wire, proceeding from the box. You vhat a hole it has made through every t of the paper. Smell the paper where ›erforation is.

iarles. It smells like sulphur.

utor. Or more like phosphorus. You rve, in this experiment, that the elec- luid passed from the inside of the jars ıgh the conducting rod and paper, to ›utside.

ımes. Why did it not pass through ›aper, in the same manner as it passed ›rass discharging rod, in which it made ole ?

ıtor. Paper is a non-conducting sub- :e, but brass is a conductor: through atter it passes without any resistance, in its endeavour to get to the in- of the box, it burst the paper as you The same thing would have hap- d had there been twice or thrice as ı paper. The electric fluid of a sin- ar will pierce through many sheets of .

Charles. Would it se
non-conducting substance in
ner?

Tutor. Yes, it will eve
piece of glass, or of resin,
wax, if they be interposed
discharging rod and the outsi
ing of the battery.

Example 2. Place a piec
gar in the situation in which
paper was just now, the sugar
ken, and in the dark it will ap
fully illuminated, and remain s
seconds of time.

Example 3. Let the small pi
proceeding from the hole in th
laid on one side of a plate, contai
spirits of wine, and, on the opp
of the plate, bring one of the kn
discharging-rod, while the other
to the wires connected with the
the jars.

Charles. Then the electric fluid
a passage through the spirit?

r. It will set it on fire instantly.

mple 4. Take two slips of common v-glass, about four inches long, and ch broad: put a slip of gold-leaf n the glasses, leaving a small part of at each end, then tie the glasses to- or press them with a heavy weight, ad the charge of the battery through connecting one end of the glass he outside of the jars, and bring- e discharging-rod to the other end, the wires of the inside of the bat-

tes. Will it break the glass?

or. It probably will: but whether it or not, the gold-leaf will be forced e pores of the glass, so as to appear ass stained with gold, which nothing ash away.

mple 5. If the gold-leaf be put be- two cards, and a strong charge pass- ough it, it will be completely fused ted, the marks of which will appear card.

This instrument, (Plate VII. Fig. 11 called an universal discharger, is very us ful for passing charges through many su stances. B B are glass pillars cement into the frame A. To each of the pill is cemented a brass cap, and a double joi for horizontal and vertical motions; the top of each joint is a spring tul which holds the sliding wires C *x*, C *x*, that they may be set at various distanc from each other, and turned in any dire tion; the extremities of the wires a pointed, but with screws, at about half inch from the points, to receive balls. T table E D, inlaid with a piece of ivory, made to move up and down in a sock and a screw fastens it to any required heig The rings C C are very convenient for f ing a chain or wire to them, which p ceeds from the conductor.

Charles. Do you lay any thing on ivory, between the balls, when you w to send the charge of a battery thr *it?*

Tutor. Yes; and by drawing out the wires, the balls may be separated to any distance less than the length of the ivory. The figure H (Plate VII. Fig. 12.) represents a press, which may be substituted in the place of the table E D. It consists of two flat pieces of mahogany, which may be brought together by screws.

James. Then instead of tying the slips of glass together in Example 4, you might have done it better by making use of the press?

Tutor. I might; but I was willing to show you how the thing might be done, if no such apparatus as this were at hand. The use of the table and press, which, in fact, always go together, is for keeping steady all descriptions of bodies through which the charge of a single jar, or any number of which a battery consists, is to be conveyed. We will now proceed with the experiments.

Example 6. I will take the knobs from the wires of the universal dischar-

ger, and having laid a piece of very dry writing paper on the table E, I place the points of the wires at an inch or more from one another; then, by connecting one of the rings C with the outside wire or hook of the battery, and bringing the discharging-rod from the other ring C to one of the knobs of the battery, you will see that the paper will be torn to pieces.

Example 7. The experiment which I am now going to make, you must never attempt by yourselves: I put a little gunpowder in the tube of a quill, open at both ends, and insert the pointed extremities of the two wires in it, so as to be within a quarter of an inch or less from each other. I now send the charge of the battery through it, and the gunpowder, you see, is instantly inflamed.

Example 8. Here is a very slender wire, not a hundredth part of an inch in diameter, which I connect with the wires of the discharger, and send the charge

of a battery through it, which will completely melt it, and you now perceive the little globules of iron instead of the thin wire.

Charles. Will other wires besides iron be melted in the same manner?

Tutor. Yes, if the battery be large enough, and the wires, sufficiently thin, the experiment will succeed with them all: even with a single jar, if it be pretty large, very slender wire may be fused. But the charges of batteries have been used to determine the different conducting powers of the several metals.

James. If the charge is not strong enough to melt the wire, will it make it red hot?

Tutor. It will: and when the experiment is properly done, the course of the fluid may be discerned by its effects: for if the wire is about three inches long, it will be seen that the end of it, which is connected with the inside of the battery, is

red-hot first, and the redness proceeds towards the other.

Charles. That is a clear proof that the superabundant electricity accumulated in the inside is carried to the outside of the jars.

Tutor. Example 9. We have in the present volume discussed the subject of magnetism: and we may here observe that by discharging the battery through a small sewing needle, it will become magnetic, that is, if the needle be accurately suspended on a small piece of cork in a basin of water, one end will, of itself, point to the north, and the other to the south.

Example 10. I will lay this chain on a sheet of writing-paper, and send the charge of the battery through the chain; and you will see black marks will be left on the paper in those places where the rings of the chain touch each other.

Example 11. Place a small piece of very dry wood between the balls of the universal dischargers so that the fibres of

the wood may be in the direction of the wires, and pass the charge of the battery through them, the wood will be torn in pieces. The points of the wires being run into the wood, and the shock passed through them, will effect the same thing.

Example 12. Here is a glass tube, open at both ends, six inches long, and a quarter of an inch in diameter. These pieces of cork, with wires in them, exactly fit the ends of the tube. I put in one cork, and fill the tube with water, then put the other cork in, and push the wires so that they nearly touch, and pass the charge of the battery through them, you see the tube is broken, and the water dispersed in every direction.*

* To prevent accidents, a wire cage, such as is used in some experiments on the air-pump, should be put over the tube before the discharge is made young persons should not attempt this experiment by *themselves.*

Charles. If water is a good conductor, how is it that the charge did not run through it without breaking the tube?

Tutor. The electric fluid, like common fire, converts the water into a highly elastic vapour, which occupying very suddenly a much larger space than the water, bursts the tube before it can effect any means of escape.

CONVERSATION XXXVII.

Of the Electric Spark, and Miscellaneous Experiments.

TUTOR. I wish you to observe some facts connected with the electric spark. By means of the wire inserted in this ball, I fix it to the end of the conductor, and bring either another brass ball, or my knuckle to it, and if the machine act pretty powerfully, a long crooked, brilliant spark, will pass between the two balls, or between the knuckle and ball. If the conductor is negative, it receives the spark from the body; but if it is positive, the ball or the knuckle receives the spark from the conductor.

Charles. Does the size of the spark depend at all on the size of the conductor?

Tutor. The longest and largest sparks are obtained from a large conductor, provided the machine act very powerfully. When the quantity of electricity is small, the spark is straight; but when it is strong, and capable of striking at a greater distance, it assumes what is called a zig-zag direction.

James. If the electric fluid is fire, why does not the spark, which excites a painful sensation, burn me, when I receive it on my hand?

Tutor. Ex. 1. I have shown you that the charge from a battery will make iron wire red-hot, and inflame gunpowder. Now stand on the stool with glass legs, and hold the chain from the conductor with one hand. Do you, Charles, hold this spoon, which contains some spirit of wine, to your brother, while I turn the machine, and a spark taken from his knuckle, if large, will set fire to the spirit.

Charles. It has indeed. Did you do nothing with the spirit?

Tutor. I only made the silver spoon pretty warm before I put the spirit into it.

Ex. 2. If a ball of box-wood be placed on the conductor instead of the brass ball, a spark taken from it will be of a fine red colour.

Ex. 3. An ivory ball placed on the conductor will be rendered very beautiful and luminous if a strong spark be taken through its centre.

Ex. 4. Sparks taken over a piece of silver leather appear of a green colour, and over gilt leather of a red colour.

Ex. 5. Here is a glass tube (Plate VII. Fig. 13.) round which, at small distances from each other, pieces of tin foil are pasted in a spiral form, from end to end: this tube is enclosed in a larger one, fitted with brass cups at each end, which are connected with the tin foil of the inner tube.—I hold one end A in my hand, and while one of you turn the machine, I will present the other end B to the conductor, to take sparks from it.—But first shut the *window-shutters*.

Charles. This is a very beautiful experiment.

Tutor. The beauty of it consists in the distance which is left between the pieces of tin foil, and by increasing the number of these distances, the brilliancy is very much heightened.

Ex. 6. The following is another experiment of the same kind. Here is a word with which you are acquainted (Plate VIII. Fig. 14.) made on glass, by means of tin-foil pasted on glass, fixed in a frame of baked wood. I hold the frame in my hand at H, and present the ball G to the conductor, and at every considerable spark the word is beautifully illuminated.

Ex. 7. A piece of sponge filled with water, and hung to a conductor, when electrified in a dark room, exhibits a beautiful appearance.

Ex. 8. This bottle is charged: if I bring the brass knob that stands out of it, to a basin of water which is insulated, it will attract a drop; and, on the removal of the bottle, it will assume a conical shape, and

brought near any conducting substance, it will fly to it in luminous streams.

Ex. 9. Place a drop of water on the conductor, and work the machine, the drop will afford a long spark, assume a conical figure, and carry some of the water with it.

Ex. 10. On this wire I have fixed a piece of sealing-wax, and having fixed the wire into the end of the conductor, I will light the wax, and the moment the machine is worked, the wax will fly off in the finest filaments imaginable.

Ex. 11. I will wrap some cotton-wool round one of the knobs of my discharging-rod, and fill the wool with finely bruised resin: I now discharge a Leyden jar, or a battery, in the common way, and the wool is instantly in a blaze. The covered knob must touch the knob of the jar, and the discharge should be effected as quickly as possible.

You will remember that the electric fluid always chooses the nearest road, and the

best conductors to travel by; in proo which take the following experiment:–

Ex. 12. With this chain I make a s of w, (Plate VII. Fig. 15.) the wire *w* touch the outside of a charged jar, and the wi *x*, is brought to the knob of the jar, an in the dark a brilliant w is visible. But i the wire *w* is contined to *m*, the electric fluid takes a shorter road to *x*, and, of course, only half of the w is seen, viz. that part marked *m z y*: but if, instead of the wire *w m*, a dry stick be laid in its place, the electric matter will prefer a longer circuit, rather than go through a bad conductor, and the whole w will be illuminated.

Ex. 13. Here is a two ounce-phial, half full of sallad-oil, through the cork is passed a piece of slender wire, the end of which, within the phial, is so bent as to touch the glass just below the surface of the oil. I place my thumb opposite the point of the wire in the bottle, and in that position ke a spark from the charged conductor. u observe that the spark, to get to my mb, has actually perforated the glass.

In the same way I can make holes all round the phial.

Charles. Would the experiment succeed with water instead of oil?

Tutor. No, it would not.

James. At any rate we see the course of the electric fluid in this experiment, for the spark comes from the conductor down the wire, and through the glass to the thumb.

Tutor. Its direction is, however, better shown in this way.

Ex. 14. At that end of the conductor which is farthest from the machine, I fix a brass wire, about six inches long, having a small brass ball on its extremity. To this ball, when the machine is at work, I hold the flame of a wax taper.

Charles. The flame is evidently blown from the ball, in the direction of the electric fluid: it has a similar effect to the blast of a pair of bellows.

Ex. 15. I will fix a pointed wire upon the prime conductor, with the point outward, and *another* like wire upon the *insulated rubber.* Shut the window-shutter,

and I will work the machine: now observe the points of the two wires.

James. They both are illuminated, but differently. The point on the conductor sends out a sort of brush of fire, but that on the rubber is illuminated with a star.

Tutor. You see then the difference between the positive and negative electricity.

CONVERSATION XXXVIII.

Miscellaneous Experiments—Of the Electrophorus—Of the Electrometer, and the Thunder House.

TUTOR. I shall proceed this morning with some other experiments on the electrical machine.

Ex. 1. Here are two wires, one of which is connected with the outside of this charged Leyden jar, the other is so bent as easily to touch the knob of the jar. The two straight ends I bring within the distance of the tenth of an inch of one another, and press them down with my thumb, and in *this position,* having darkened the room, I discharged the jar. Do you look upon my *thumb.*

Charles. It was so transparent that I think I even saw the bone of the thumb.—But did it not hurt you very much?

Tutor. With attention, you might observe the principal blood vessels, I believe; and the only inconvenience that I felt was a sort of tremour in my thumb, which is by no means painful. Had the wires been at double the distance, the shock would have probably made my thumb the circuit, which must have caused a more powerful and unpleasant sensation, but being so close, the electric fluid leaped from one wire to the other, and during this passage it illuminated my thumb, but did not go through it.

Ex. 2. If, instead of my thumb, a decanter full of water, having a flat bottom, were placed on the wires, and the discharge made, the whole of the water will be beautifully illuminated.

Ex. 3. This small pewter bucket is full of water, and I suspend it from the prime conductor, and put in a glass syphon, with a bore so narrow that the water will hardly drop out. See what will happen when

work the machine; but first make the room dark.

James. It runs now in a full stream, or rather in several streams, all of which are illuminated.

Tutor. Ex. 4. If the knob *a* (Plate VIII. Fig. 16.) communicate with the outside of a charged Leyden jar, and the knob *b* with the inside coating, and each be held about two inches from the lighted candle *x*, and opposite to one another, the flame will spread towards each, and a discharge will be made through it: this shows the conducting power of flame.

This instrument (Plate VIII. Fig. 17.) which consists of two circular plates, of which the largest B is about fifteen inches in diameter, and the other A fourteen inches, is called an *electrophorus.* The *under* plate B is made of glass, or sealing-wax, or of any other non-conducting substance: I have made one with a mixture of pitch and chalk *boiled together.* The upper plate A is sometimes made of brass, and sometimes of tin plate, but this is of wood, covered very

neatly with tin foil: *x* is a glass handle fixed to a socket, by which the upper plate is removed from the under one.

Charles. What do you mean by an electrophorus?

Tutor. It is, in fact, a sort of simple electrical machine, and is thus used. Rub the lower plate B with a fine piece of new flannel, or with rabbit's, or hare's, or cat's skin, and when it is well excited, place upon it the upper plate A, and put your finger on the upper plate: then remove this plate by the glass handle *x*, and if you apply your knuckle, or the knob of a coated jar, you will obtain a spark. This operation may be repeated many times without exciting again the under plate.

James. Can you charge a Leyden jar in this way?

Tutor. Yes, it has been done, and by a single excitation, so as to pierce a hole through a card.

Here is another kind of electrometer (Plate VIII. Fig. 18.) which is by far the most sensible that has been yet invented

that is, it is capable of discovering the smallest quantities of electricity. A is a glas jar, B the cover of metal, to which are attached two pieces of gold leaf x, or two pith-balls suspended on threads: on the sides of the glass jar are two narrow strips of tin foil.

Charles. How is this instrument used?

Tutor. Any thing that is electrified is to be brought to the cover, which will cause the pieces of gold leaf, or pith-balls to diverge; and the sensibility of this instrument is so great that the brush of a feather, the throwing of chalk, hair-powder, or dust, against the cap B, evinces strong signs of electricity.

Ex. 5. Place, on the cap B, a little pewter, or any other metallic cup, having some water in it: then take from the fire a live cinder, and put it in the cup, and the electricity of vapour is very admirably exhibited.

A thunder-cloud passing over this instrument will cause the gold leaf to strike the sides at every flash of lightning.

Ex. 6. I will excite this stick of sealing-wax and bring it to the cover B: you see how often it causes the gold leaf to strike against the sides of the glass.

James. Are the slips of tin foil intended to carry away the electric fluid communicated by the objects presented to the cap B?

Tutor. They are; and by them the equilibrium is restored.

CONVERSATION XXXIX.

Of Atmospherical Electricity.

CHARLES. You said yesterday, that the electrometer was affected by thunder and lightning: are lightning and electricity similar?

Tutor. They are, undoubtedly, the same fluid; and they are the same, was discovered by Dr. Franklin more than half a century ago.

James. How did he ascertain this fact?

Tutor. He was led to the theory from observing the power which uninsulated *points* have in drawing off the electricity from bodies. And having formed his system, he

Tutor. You know how easy it is to charge a Leyden jar: but if, when the machine is at work, a person hold a point of steel, or other metal, near the conductor, the greater part of the fluid will run away by that point instead of proceeding to the jar. Hence it was concluded that pointed rods would silently draw away the lightning from clouds passing over any building.

James. Is there not a particular method of fixing them?

Tutor. Yes: the metallic rod must reach from the ground, or the nearest piece of water, to a foot or two above the building it is intended to protect, and the iron rod should come to a fine point. Some electricians recommend that the point should be of gold, to prevent its rusting.

Charles. What effects would be produced, if lightning should strike a building withot a conductor?

Tutor. That may be best explained, by informing you of what happened, many years ago, to St. Bride's church. The light-

ning first struck the weathercock, from thence descending in its progress, it beat out a number of large stones of different heights, some of which fell upon the roof of the church, and did great damage to it. The mischief done to the steeple was so considerable, that eighty-five feet of it was obliged to be taken down.

James. The weathercock was probably made of iron, why did not that act as a conductor?

Tutor. Though that was made of iron, yet it was completely insulated by being fixed in stone, that had become dry by much hot and dry weather. When therefore the lightning had taken possession of the weather-cock, by endeavouring to force its way to another conductor, it beat down whatever stood in its way.

Charles. The power of lightning must be very great.

Tutor. It is irresistible in its effects; the following experiment will illustrate what I have been saying.

Ex. 1. A is a board (Pate VIII. Fig. 19.) representing the gable end of a house: it fixed on another board B: $a\ b\ c\ d$ is a square hole, to which a piece of wood is fitted; $a\ c$ represents a wire fixed diagonally on the wood $a\ b\ c\ d$; $x\ b$ terminated by a knob x represents a weathercock, and the wire c is fixed to the board A.

It is evident that in the state in which it is drawn in the figure, there is an interruption in the conducting rod; accordingly, if the chain m is connected with the outside of a Leyden phial, and then that phial is discharged through x, by bringing one part of the discharging rod to the knob of the Leyden phial, and the other to within an inch or two of x, the piece of wood $a\ b\ c\ d$ will be thrown out with violence.

James. Are we to understand by this experiment, that if the wire $x\ b$ had been continued to the chain, that the electric fluid would have run through it without disturbing the loose board?

Tutor. Ex. 2. Just so; for if the piece of wood be taken out, and the part $a\ b$

to the place *b*, then *d* will come to *c*, and the conducting rod will be complete, and continued from *x* through *b c* to *z*, and now the phial may discharged as often as you please, but the wood will remain in its place, because the electric fluid runs through the wire to *z*, and makes its way by the chain to the outside of the phial.

Charles. Then if *x* be supposed the weathercock of the church, the lightning having overcharged this, by its endeavours to reach another conductor, as *c z*, forced away the stone or stones represented by *a b c d*?

Tutor. That is what I meant to convey to your minds by the first experiment; and the second shows very clearly that if an iron rod had gone from the weathercock to the ground, without interruption, it would have conducted away the electricity silently, and without doing any injury to the church.

James. How was it that all the stone were not beaten down?

Tutor. Because, in its passage down-

wards, it met with many other conductors. I will read part of what Dr. Watson says on this fact, who examined it very attentively :—

"The lightning," says he, "first took a weathercock, which was fixed at the top of the steeple, and was conducted without injuring the metal or any thing else, as low as where the large iron bar or spindle which supported it terminated; there the metallic communication ceasing, part of the lightning exploded, cracked and shattered the obelisk which terminated the spire of the steeple, in its whole diameter, and threw off, at that place, several large pieces of Portland stone. Here it likewise removed a stone from its place, but not far enough to be thrown down. From thence the lightning seemed to have rushed upon two horizontal iron bars, which were placed within the building cross each other. At the end of one of these iron bars, it exploded again, and threw off a considerabe quantity of stone. Almost all the damage was done where the ends of the

iron bars had been inserted into the stone, or placed under it; and, in some places, its passage might be traced from one iron bar to another."

The thunder holds his black tremendous throne:
From cloud to cloud the rending lightnings rage;
Till, in the furious elemental war
Dissolv'd the whole precipitated mass
Unbroken floods and solid torrents pours.

THOMSON.

CONVERSATION XL.

On Atmospheric Electricity—Of Falling Stars—O Aurora Borealis—Of Water-spouts, and Whirlw —Of Earthquakes.

CHARLES. Does the air always con electricity?

Tutor. Yes; and it is owing to the e tricity of the atmosphere that we obser number of curious and interesting ph mena, such as falling stars; the aurora eralis, or northern lights; the ignis fat or Will-with-the-wisp.

James. I have frequently seen w people call falling stars, but I never kı that they were occasioned merely by e rticity.

Tutor. These are seen chiefly in clear and calm weather: it is then that the electric fluid is probably not very strong, and passing through the air it becomes visible in particular parts of its passage, according to the conducting substances it may meet with. One of the most striking phenomena of this kind is recorded by Signior Beccaria.—As he was sitting with a friend in the open air, an hour after sun-set, they saw a falling, or, as it is sometimes called, a shooting star, directing its course towards them, growing, apparently, larger and larger, till it disappeared not far from them, and, disappearing, it left their faces, hands, and clothes, with the earth and neighbouring objects, suddenly illuminated with a diffused and lambent light, attended with no noise at all.

Charles. But how did he know that this was only the effect of electricity?

Tutor. Because he had previously raised his kite, and found the air very much *charged with* the electric matter: sometimes

he saw it advancing to his kite like a fal ing star; and sometimes he saw a kind glory round it, which followed it as changed its place.

James. Since lofty objects are expos to the effects of lightning, or the elect fluid, do not the tall masts of ships, r considerable risk of being struck by it?

Tutor. Certainly: we have many inst ces recorded of the mischief done to shi One of which is related in the Philo phical Transactions; it happened on bo the Montague, on the 4th of Novemb 1748, in latitude 42° 48′ and 9° 3′ w longitude, about noon. One of the qu te-masters desired the master of the v sel to look to the windward, when he served a large ball of blue fire, roll apparently on the surface of the water the distance of three miles from them. rose almost perpendicular when it within forty or fifty yards from the ma chains of the ship, it then went off with explosion, as if a hundred cannon

een fired at one time, and left so strong a smell of sulphur, that the ship seemed to contain nothing else. After the noise had subsided, the main top-mast was found shattered to pieces, and the mast itself was rent quite down to the keel. Five men were knocked down, and one of them greatly burnt by the explosion.

Charles. Did it not seem to be a very large ball to have produced such effects?

Tutor. Yes: the person who noticed it said it was as big as a mill-stone.

The aurora borealis is another electrical phenomenon: this is admitted without any hesitation, because electricians can readily imitate the appearance with their experiments.

James. It must be, I should think, on a very small scale.

Tutor. True: there is a glass tube about thirty inches long, and the diameter of it is about two inches; it is nearly exhausted of air, and capped on both ends *with brass. I now* connect these ends by

means of a chain, with the positive and negative part of a machine, and in a darkened room, you will see, when the machine is worked, all the appearances of the northern lights in the tube.

Charles. Why is it necessary nearly to exhaust the tube?

Tutor. Because the air, in its natural state, is a very bad conductor of the electric fluid; but when it is, perhaps, rendered some hundred times rarer than it usually is, the electric fluid darts from one cap to the other, with the greatest ease.

James. But we see the aurora borealis in the common air.

Tutor. We do so: it is, however, in the higher regions of the atmosphere where the air is much rarer than it is near the surface of the earth. The experiment which you have just seen accounts for the darting and undulating motion which takes place between the opposite parts of the heavens. The aurora borealis is the most beautiful and brilliant in countries in the

high northern latitudes, as in Greenland and Iceland.

Charles. I remember the lines on this subject:

> By dancing meteors then, that ceaseless shake
> A waving blaze refracted o'er the heavens,
> And vivid moons, and stars that keener play
> With double lustre from the glossy waste,
> Ev'n in the depth of polar night, they find
> A wond'rous day; enough to light the chase,
> Or guide their daring steps to Finland fairs.

Tutor. The aurora borealis that was seen in this country on the 23d of October, in the year 1804, is deserving of notice. At seven in the evening a luminous arch was seen from the centre of London, extending from one point of the horizon, about S. S. W. to another point N. N. W. and passing the middle of the constellation of the Great Bear, which it, in a great measure, *obscured.* It appeared t

shining vapour, and to roll from the south to the north. In about half an hour, its course was changed; it then became vertical, and about nine o'clock it extended across the heavens from N. E. to S. W.; at intervals, the continuity of the luminous arch was broken, and there then darted from its south-west quarter, towards the zenith, strong flashes and streaks of bright red, similar to what appears in the atmosphere during a great fire in any part of the metropolis. For several hours the atmosphere was as light in the south-west as if the sun had set but half an hour; and the light in the north resembled the strong twilight which marks that part of the horizon at Midsummer. Thomson, speaking of the aurora borealis, and other meteors, says—

——————Silent from the north,
A blaze of meteors shoots; ensweeping first
The lower skies, they all at once converge
High to the crown of heaven, and all at once

Relapsing quick, as quickly re-ascend,
And mix and thwart, extinguish and renew,
All æther coursing in a maze of light.

James. How do you account, sir, for he Will-with-the-wisp, or Jack-a-lanthorn, hat is close to the ground where the air is hickest?

Tutor. This is a meteor which seldom ppears more than six feet above the round; it is always about bogs and rampy places, and these, in hot weather, nit what is called inflammable air, which easily inflamed by the electric spark. hese, therefore, as you shall see in our emical experiments, we can as readily itate as the aurora borealis.—In some rts of Italy, meteors of this kind are equently very large, and give a light equal that of a torch.

Water-spouts, which are sometimes see n sea, are supposed to arise from the ver of electricity.

Charles. I have heard of these, but thought that water-spouts at sea, and wh winds and hurricanes by land, were pro ced solely by the force of the wind.

Tutor. The wind is, undoubtedly, of the causes, but it will not account every appearance connected with th Water-spouts are often seen in calm w ther, when the sea seems to boil, and se up a smoke under them, rising in a sort hill towards the spout. A rumbling no is often heard at the time of their appe ance, which happens generally in th months that are peculiarly subject to th der-storms, and they are commonly companied or followed by lightning. W these approach a ship, the sailors pres and brandish their swords to disperse th which seems to favour the conclusion, t they are electrical.

James. Do the swords act as conc tors ?

Tutor. They may, certainly ; and i known that by these pointed instrum they have been effectually dispersed.

The analogy between the phenomena of water-spouts, and electricity, may be made visible by hanging a drop of water to a wire, communicating with the prime conductor, and placing a vessel of water under it. In these circumstances, the drop assumes all the various appearances of a water-spout, in its rise, form, and mode of disappearing.

Water-spouts, at sea, are undoubtedly very like whirlwinds and hurricanes by land. These sometimes tear up trees, throw down buildings, make caverns; and, in all the cases, they scatter the earth, bricks, stones, timber, &c. to a great distance in every direction. Dr. Franklin, mentions a remarkable appearance which occurred to Mr. Wilke, a consdierable electrician. On the 20th of July, 1758, at three o'clock in the afternoon, he observed a great quantity of dust rising from the ground, and covering a field, and part of the town in which he then was. There *was no wind*, and the dust moved gently

towards the east, where there appeared a great black cloud, which electrified his apparatus positively to a very high degree. This cloud went towards the west, the dust followed it, and continued to rise higher and higher, till it composed a thick pillar in the form of a sugar loaf, and at length it seemed to be in contact with the cloud. At some distance from this, there came another great cloud, with a long stream of smaller ones which electrified his apparatus negatively, and when they came near the positive cloud, a flash of lightning was seen to dart through the cloud of dust, upon which the negative clouds spread very much, and dissolved in rain, which presently cleared the atmosphere.

Charles. Is rain then an electrical phenomenon?

Tutor. The most enlightened and best informed electricians reckon rain, hail, and snow, among the effects produced by the electric fluid.

James. Do the negative and positive clouds act in the same manner as the outside and inside coatings of a charged Leyden jar?

Tutor. Thunder-clouds frequently do nothing more than conduct or convey the electric matter from one place to another.

Charles. Then they may be compared to the discharging-rod.

Tutor. And perhaps, like that, they are intended to restore the equilibrium between two places, one of which has too much, and the other too little of the electric fluid. The following is not an uncommon appearance: a dark cloud is observed to attract others to it, and when grown to a considerable size, its lower surface swells in particular parts towards the earth. During the time that the cloud is thus forming, flashes of lightning dart from one part of it to the other, and often illuminate the whole mass; and small clouds are observed moving rapidly beneath it. When the *cloud has* acquired a sufficient extent, the

lightning strikes the earth in two opposite places.

James. I wonder the discharge does not shake the earth, as the charge of a jar does any thing through which it passes.

Tutor. Every discharge of clouds through the earth may do this, though it is imperceptible to us.

Earthquakes are probably occasioned by vast discharges of the electric fluid: they happen most frequently in dry and hot countries, which are subject to lightning, and other electric phenomena: they are even foretold by the electric coruscations, and other appearances in the air for some days preceding the event. Besides, the shock of an earthquake is instantaneous to the greatest distances. Earthquakes are usually accompanied with rain, and sometimes by the most dreadful thunder-storms:

> How greatly terrible how dark and deep
> The purposes of Heaven! At once o'erthrown,

White age and youth, the guilty and the just,
Oh, seemingly severe! promiscuous fall.
Reason, whose daring eye in vain explores
The fearful Providence, confused, subdued
To silence and amazement, with due praise
Acknowledges th' Almighty, and adores
His will unerring, wisest, justest, best.

MALLET.

CONVERSATION XLI.

Medical Electricity.

TUTOR. If you stand on the with glass legs, and hold the chain the conductor while I work the m a few minutes, your pulse will be incr that is, it will beat more frequently t did before. From this circumstance sicians have applied electricity to th of many disorders: in some of which endeavours have been unavailing, in the success has been very complete.

Charles. Did they do nothing more this?

Tutor. Yes, in some cases they took ɔarks from their patients, in others they ıve them shocks.

James. This would be no pleasant meıod of cure, if the shocks were strong.

Tutor. You know, by means of Lane's ectrometer, described in our thirty fourth onversation, (Plate VII. Fig. 10.) the shock ay be given as slightly as you please.

Charles. But how are shocks conveyed rough any part of the body?

Tutor. There are machines and appatus made purposely for medical purposes, ıt every end may be answered by the strument just referred to. Suppose the ectrometer to be fixed to a Leyden phi-, and the knob at A to touch the conducr, and the knob B to be so far off as ɔu mean the shocks to be weak or strong, chain or wire of sufficient length is to be xed to the ring C of the electrometer, and ıother wire or chain to the outside coatıg: the other ends of these two wires are be fastened to the two knobs of the disıarging-rod.

James. What next is to be done i wish to electrify my knee, for instance?

Tutor. All you have to do is to br the balls of the discharging-rod close your knee, one on the one side, and other on the opposite side.

Charles. And at every discharge of Leyden jar, the superabundant electr from withinside will pass from the at A to the knob B, and will pass thr the wire and the knee, in its way to outside of the jar, to restore to both an equilibrium.

James. But if it happen that a pa the body, as an arm, is to be electr how is it to be done, because in that I cannot use both my hands in con ing the wires?

Tutor. Then you may seek the tance of a friend, who will, by mear two instruments, called *directors*, be to conduct the fluid to any part of the whatever.

Charles. What are directors?

Tutor. A director consists of a k

d brass wire, which, by means of a brass p, is cemented to a glass handle. So the erator holding these directors by the ex- emities of the glass handle, brings the balls, which the wires or chains are attached, to contact with the extremities of that art of the body of the patient through hich the shock is to be sent. If I feel eumatic pains between my elbow and rist, and a person hold one director at the bow and another about the wrist, the ocks will pass through, and probably will found useful in removing the complaint.

James. Is it necessary to stand on the ass-footed stool to have this operation erformed?

Tutor. By no means: when shocks are lministered, the person who receives them ay stand as he pleases, either on the stool, on the ground; the electric fluid taking e nearest passage, will always find the ther knob of the other director, which leads the outside of the jar.

Charles. Is it necessary to make the body are?

Tutor. Not in the case of shocks, u
the coverings be very thick: but when s|
are to be taken, then the person from w
they are drawn must be insulated, an
clothes should be stripped off the pa
fected.

James. For what disorders are the s
and sparks chiefly used?

Tutor. Shocks have been found us
paralytic disorders; in contractions
nerves; in sprains, and in many other
but great attention is necessary in regu
the force of the shock, because, inst
advantage, mischief may occur if it
violent.

Charles. Is there less danger with s|

Tutor. Yes; for unless it be in very
parts, as the eye, there is no great r
taking sparks: and they have provec
effectual in removing many complain

The celebrated Mr. Ferguson was s
at Bristol, with a violent sore throat,
to prevent him from swallowing any
he caused sparks to be taken from th

...ected, and in the course of an hour he ...ld eat and drink without pain.

This is an excellent method in cases of ...fness, ear-ache, tooth-ache, swellings ...ide the mouth, &c.

James. Would not strong sparks injure ...e ear?

Tutor. They might; and therefore the ...ectric fluid is usually drawn with a point-...d piece of wood, to which it comes in a ...ream, or when sparks are taken, a very ...mall brass ball is used, because, in pro-...ortion to the size of the ball, is the size of ...he spark

CONVERSATION XLII.

Of Animal Electricity: of the Torpedo; of the Gymnotus Electricus, and of the Silurus Electricus.

TUTOR. There are three kinds of fish which have been discovered that are possessed of the singular property of giving shocks very similar to those experienced by means of the Leyden jar.

Charles. I should like much to see them: are they easily obtained?

Tutor. No, they are not: they are called the *torpedo*, the *gymnotus electricus*, and the *silurus electricus.*

James. Are they all of the same species?

Tutor. No: the torpedo is a flat fish, seldom twenty inches long, and is common

in various parts of the sea coast of Europe. The electric organs of this fish are placed on each side of the gills, where they fill up the whole thickness of the animal, from the lower to the upper surface, and are covered by the common skin of the body.

Charles. Can you lay hold of the fish by any other part of the body with impunity?

Tutor. Not altogether so: for if it be touched with one hand, it generally communicates a very slight shock; but if it be touched with both hands at the same time, one being applied to the under, and the other to the upper surface of the body, a shock will be received similar to that which is occasioned by the Leyden jar.

James. Will not the shock be felt if both hands be put on one of the electrical organs at the same time?

Tutor. No: and this shows that the upper and lower surfaces of the electric organs are in opposite states of electricity, answering to the positive and negative sides of a Leyden phial.

Charles. Are the same substances conductors of the electric power of the torpedo, by which artificial electricity is conducted?

Tutor. Yes, they are: and if the fish, instead of being touched by the hands, be touched by conducting substances as metals, the shock will be communicated through them. The circuit may also be formed by several persons joining hands, and the shock will be felt by them all at the same time. But the shock will not pass where there is the smallest interruption; it will not even be conducted through a chain.

James. Can you get sparks from it?

Tutor. No spark was ever obtained from the torpedo, nor could electric repulsion and attraction be produced by it.

Charles. Is it known how the power is accumulated?

Tutor. It seems to depend on the will of the animal, for each effort is accompanied with a depression of its eyes, and it probably makes use of it as a means of self-defence.

nes. Is this the case also with the other ical fishes?

tor. The *gymnotus* possesses all the ic properties of the torpedo, but in a superior degree. This fish has been l the electrical eel, on account of its ablance to the common eel. It is found e large rivers of South America.

arles. Are these fishes able to injure s by this power?

tor. If small fishes are put into the r in which the gymnotus is kept, it will stun, or perhaps kill them, and if the al be hungry, it will then devour them. ishes stunned by the gymnotus may be vered, by being speedily removed into ier vessel of water.

ie gymnotus is said to be possessed of w kind of sense, by which it knows her bodies, which are brought near are conductors or not.

arles. Then it possesses the same ledge by instinct which philosophers gained by experiment.

Tutor. True, The following experiment, among others, is very decisive on this point.

Ex. The extremities of two wires were dipped into the water of the vessel in which the animal was kept; they were then bent, extended a great way, and terminated in two separate glasses full of water. These wires, being suppored by non-conductors, at a considerable distance from each other, the circuit was incomplete: but if a person put the fingers of both hands into the glasses in which the wires terminated, then the circuit was complete. While the circuit was incomplete, the fish never went near the extremities of the wires, as if desirous of giving the shock; but the moment the circuit was completed, either by a person, or any other conductor, the gymnotus immediately went towards the wires, and gave the shock, though the completion of the circuit was out of his sight.

James. How do they catch these kind of fish; the men would, probably, let them go on receiving the shock?

Tutor. In this way the property was,

perhaps, first discovered. The gymnotus, as well as the others, may be touched, without any risk of the shock, with wax or with glass; but if it be touched with the naked finger, or with a metal, or a gold ring, the shock is felt up the arm.

Charles. Does the *silurus electricus* produce the same effects as the others?

Tutor. This fish is found in some rivers in Africa, and it is known to possess the property of giving the shock, but no other particulars have been detailed respecting it.

With regard to the torpedo, its power of giving the benumbing sensation was known to the ancients, and from this it probably took its name.—In Fermin's Natural History of Surinam is some account of the *trembling-eel*, which Dr. Priestley conjectures to be different from the gymnotus: it lives in marshy places, from whence it cannot be taken, except when it is intoxicated. It cannot be touched with the hand, or with a stick, without feeling a terrible shock. If trod upon with shoes, the legs and thighs are affected in a similar manner.

CONVERSATION XLIII.

General Summary of Electricity, with Experiments

TUTOR. You now understand what electricity is?

Charles. Yes, it is a fluid which seems to pervade all substances, and when undisturbed, it remains in a state of equilibrium.

James. And that certain portion which every body is supposed to contain, is called its natural share.

Tutor. When a body is possessed of more, or retains less, than its natural share, it is said to be *charged* or electrified.

Charles. If it possess more than its natural share, it is said to be *positively* electri-

ed; but if it contain less than its natural hare, it is said to be *negatively* electrified.

Tutor. Does it not sometimes happen, hat the same substance is both positively nd negatively electrified at the same time?

James. Yes: the Leyden jar is a striing instance of this, in which, if the inside ontain more than its natural share, the outde will contain less than its natural quanty.

Tutor. What is the distinction between onductors and non-conductors of electriity?

Charles. The electric fluid passes freely hrough the *former*, but the *latter* oppose s passage.

Tutor. You know that electricity is exited in the greatest quantities, by the friction of conducting and non-conducting subtances against each other.

Ex. Rub two pieces of sealing-wax, or wo pieces of glass together, and only a very mall portion of electricity can be obtained; herefore the rubber of a machine should be a conducting substance, and not insulated.

Every electrical machine, with ted rubber, will act in three differ the rubber will produce *negative* e the conductor will give out *positi* city: and it will communicate bo at once to a person or substance p tween two directors connected wit

James. How does the rubbe negative electricity?

Tutor. If you stand on a stool legs, or upon any other non-condu stance, and lay hold of the rubber, that communicates with it, the wo machine will take away from you ty of your natural electricity, ther will be negatively electrified.

Charles. Will this appear by ture of the electric fluid, if I ho hand a steel point, as a needle?

Tutor. If you, standing on a ducting substance, are connected the rubber, and your brother, in situation, connected with the condu points in your hands, and I, whil

on the ground, first present a brass ball, or other substance, to the needle in your hand, and then to that in his hand, the appearance of the fluid will be different in both cases; to the needle in your hand it will appear like a star, but to that in your brother's it will be rather in the form of a brush.—What will happen if you bring two bodies near to one another that are both electrified?

James. If they are both positively or both negatively electrified, they will repel each other, but if one is negative and the other positive, they will attract one another till they touch, and the equilibrium is again restored.

Tutor. If a body containing only its natural share of electricity, be brought near to another that is electrified, what will be the consequence?

Charles. A quantity of electricity will force itself through the air in the form of a spark.

Tutor. When two bodies approach each other, *one* electrified positively and the *other* negatively, the superabundant electri-

Tutor. And if a conducting communication be made between both sides of the glass, what takes place then?

Charles. A discharge; and this happens whether the glass be flat, or in any other form.

Tutor. What do you call a cylindrical glass vessel thus coated for electrical purposes?

James. A Leyden jar; and when the insides, and also the outsides, of several of these jars are connected, it is called an electrical battery.

Tutor. Electricity, in this form, is capable of producing the most powerful effects, such as melting metals, firing spirits, and other inflammable substances.—What effect has metallic points on electricity?

Charles. They discharge it silently, and hence their great utility in defending buildings from the dire effects of lightning.—Pray, what is thunder?

Tutor. As lightning appears to be the rapid motion of vast masses of electric matter, so thunder is the noise produced by th

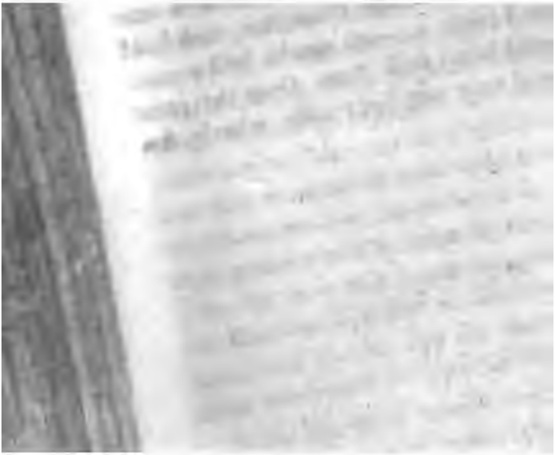
motion of lightning: and when electricity passes through the higher parts of the atmosphere, where the air is very much rarefied, it constitutes the aurora borealis.

Ex. If two sharp pointed wires be bent (Plate VIII. Fig. 30.) with the four ends at right angles, but pointing different ways, and they be made to turn upon a wire fixed on the conductor, the moment it is electrified, a flame will be seen at the points *a b c d;* the wire will begin to turn round in the direction opposite to that to which the points are turned, and the motion will become very rapid.

If the figures of horses, cut in paper, be fastened upon these wires, the horses will seem to pursue one another, and this is called the electrical horse-race. Of course, upon this principle, many other amusing and very beautiful experiments may be made: and upon this principle several electrical orreries have been contrived, showing the motions of the earth and moon, and the earth and planets round the sun.

James. How do you account for this?

Tutor. Fix a sharp pointed wire into the end of the large conductor, and hold your hand near it:—no sparks will ensue; but a cold blast will come from the point which will turn any light mills, wheels, &c.



GALVANISM,

OR

VOLTAISM.

CONVERSATION XLIV.

Of Galvanism; its Origin: Experiments.—Of the Decomposition of Water.

TUTOR. It has been observed as long as I can remember, and probably before I was born, that porter, when taken from a pewter pot, had a superior flavour than when drunk out of a glass or of china.

Charles. Yes; I have often heard my uncle say so; but what is the reason of it?

Tutor. Admitting the fact, which is, I believe, generally allowed by those who are much accustomed to that beverage; it is now explained upon the principles of *Galvanism*.

James. Is Galvanism another branch of science? is there a Galvanic fluid as well as an electric fluid?

Tutor. Of the existence of the electric fluid you now have no doubt; the science of electricity took its name from *electron*, the Greek word for amber, because amber was one of the first substances observed to produce, by rubbing, the effects of attraction and repulsion. Galvanism derives its name from Dr. Galvani, who first reported to the philosophical world the experiments on which the science is founded.

Charles. Pray how was he led to make the experiments?

Tutor. Galvani, a professor of anatomy at Bologna, was one evening making some electrical experiments, and on the table where the machine stood, were some frogs skinned: by an accident one of the company touched the main nerve of a frog, at the same moment that he took a considerable spark from the conductor of the electrical machine, and the muscles of the frog were thrown into strong convulsions. These,

which were observed by Galvani's wife, led the professor to a number of experiments, but as they cannot be repeated without much cruelty to living animals, I shall not enter into a detail of them.

James. Were not the frogs dead which first led to the discovery?

Tutor. Yes, they were: but the professor afterwards made many experiments upon living ones, whence he found that the convulsions, or as they are usually called, the contractions produced on the frog, may be excited without the aid of any apparent electricity, merely by making a communication between the nerves and the muscles with substances that are conductors of electricity.

Charles. Which are the best conducting substances?

Tutor. All the metals: but zinc and silver, or zinc and copper, produce the greatest muscular contractions.

Charles. Are these experiments peculiar to frogs?

Tutor. No; they have been successfully made on almost all kinds of animals from

the ox downwards to the fly. And hence it was at first concluded that there was an electricity peculiar to animals.

James. You have already shown that the electric fluid exists in our bodies, and may be taken from them, independently of that which causes the contractions.

Tutor. I will show you an experiment on this subject:—here is a thin piece of *zinc*, which is a sort of metallic substance, but not what is denominated a perfect metal: lay it *under* your tongue, and lay this half-crown *upon* the tongue; do you taste any thing very peculiar in the metals?

James. No, nothing at all.

Tutor. Put them in the same position again, and now bring the edges of the two metals into contact, while the other parts touch the under and upper surfaces of the tongue.

James. Now they excite a very disagreeable taste, something like copperas.

Tutor. Instead of the half-crown, try the experiment with a guinea, or with a piece of charcoal.

Charles. I perceive the same kind of taste which James described. How do you explain the fact?

Tutor. Some philosophers maintain that the principle of Galvanism and electricity is the same: and that the former is the evolution or emission of the electric fluid from *conducting* bodies, disengaged by a chemical process; while the latter is the same thing made apparent to the senses by *non-conducting* bodies.

James. All metals, as we have seen, are conducting substances; of course, the zinc, the guinea, and the half-crown, are conductors.

Tutor. Yes, and so are the tongue and the saliva; and it is probable, that by the decomposition of some small particles of the saliva the sharp taste is excited.

Charles. What do you mean by the decomposition of the saliva?

Tutor. We shall, in our chemistry, show you that water is capable of being decomposed, that is, separated into two gasses, called hydrogen and oxygen.

James. Is saliva capable of being
parated?

Tutor. Certainly, because a grea
it may be supposed to be water;
oxygen combines with the metal, w
hydrogen escapes, and excites the
the tongue.

Charles. The disagreeable taste
tongue cannot be disputed, but the
apparent change on the zinc or
crown, which there ought to be
substance, as the oxygen, has ente
the combination.

Tutor. The change is, perhaps, t
to be perceived in this experiment
others on a larger scale, it will be very
to the sight, by the *oxidation* of the

James. Here is another strange
do not know what is meant by oxi

Tutor. The iron bars fixed before
dow were clean and almost bright w
ced there last summer.

James. But not being painted, they
come quite rusty.

Tutor. Now, in chemical langu

iron is said to be oxidated instead of rusty; and the earthy substance that may be scraped from them, used to be called the *calx* of iron; but it is, by modern chemistry, denominated the oxide of iron.

When mercury loses its fine brightness by being long exposed to the air, the dulness is occasioned by oxidation, that is, the same effect is produced by the air on the mercury, as it was on the iron. I will give you another instance. I will melt some lead in this ladle, you see a scum is speedily formed. I take it away, and another will arise, and so perpetually till the whole lead is thus transformed into an apparently different substance: this is called the oxide of lead.

CONVERSATION XLV.

Galvanic Light and Shocks.

CHARLES. We had a *taste* of the Galvanic fluid yesterday, is there no way of seeing it?

Tutor. Put this piece of zinc between the upper lip and the gums, as high as you can, and then lay a half-crown, or guinea, upon the tongue, and when so situated bring the metals into contact.

Charles. I thought I saw a faint flash of light.

Tutor. I dare say you did, it was for

hat purpose I bade you make the experiment. It may be done in another way; by putting a piece of silver up one of the nostrils, and the zinc on the upper part of the tongue, and then bringing the metals in contact, the same effect will be produced.

James. By continuing the contact of the two metels, the appearance of light does not remain.

Tutor. No, it is visible only at the moment of making the contact. You may, if you make the experiment with great attention, put a small slip of tin foil over the ball of one eye, and hold a tea-spoon in your mouth, and then upon the communication between the spoon and the tin a faint light will be visible. These experiments are best performed in the dark.

Charles. Is there no means of making experiments on a larger scale?

Tutor. Yes, we have Galvanic, or, as they ought to be denominated, *Voltaic*,

from Volta,* the inventor of them, batteries, as well as electrical batteries. Here is one of them. (Plate VIII. Fig. 20.) It consists of a number of pieces of silver, zinc, and flannel cloth, of equal sizes; and they are thus arranged, a piece of zinc, a piece of silver, and a piece of cloth moistened with a solution of salt in water, and so on till the pile is completed. To prevent the pieces from falling, they are supported on the sides by three rods of glass stuck into a piece of wood, and down these rods slides another piece of wood which keeps all the pieces in close contact.

---

* Galvani's discoveries were the result of mere accident, and even but trifling, in comparison of those made by Volta, a celebrated Italian, who improved the few hints before him into an important body of science: hence the term Voltaism will shortly, without doubt, supersede that of Galvanism.

James. How do you make use of this instrument?

Tutor. Touch the lower piece of metal with one hand, and the upper one with the other.

James. I felt an electric shock.

Tutor. And you may take as many as you please: for as often as you renew the contact, so often will you feel the shock.

Here is a different apparatus (Plate VIII. Fig. 21.) In these three glasses (and I might use twenty instead of three) is a solution of salt and water. Into each, except the two outer ones, is plunged a small plate of zinc, and another of silver. These plates are made to communicate with each other, by means of a thin wire, fastened so that the silver of the first glass is connected with the zinc of the second; the silver of the second with the zinc of the third, and so on: now if you dip one hand into the first glass, and the other into the last, the shock is felt.

Charles. Will any kind of glasses answer for this experiment?

Tutor. Yes they will: wine-glasses, or goblets, or finger glasses; and so will china cups.

A third kind of battery, which is the most powerful, and the one that is most generally used, is this. It consists of a trough of baked wood, three inches deep, and about as broad. In the sides of this trough are grooves opposite to each other, and about a quarter of an inch asunder. Into each pair of these grooves is put a plate of zinc, and another of silver, and they are to be cemented in such a manner as to prevent any communication between the different cells. The cells are now filled with a solution of salt and water. The battery is complete; with your hands make a communication between the two end cells.

Charles. I felt a strong shock.

Tutor. Wet your hands, and join your left with James's right, then put your right hand into one end cell, and let James put his left into the opposite one.

James. We both felt the shock like an electric shock, but not so severe.

Tutor. Several persons may receive the shock together, by joining hands, if their hands are well moistened with water. The strength of the shock is much diminished by passing through so long a circuit. The shock from a battery, consisting of fifty or sixty pairs of zinc and silver, or zinc and copper, may be felt as high as the elbows. And if five or six such batteries be united with metal cramps, the combined force of the shock would be such that few would willingly take it a second time.

Charles. What are the wires for at each end of the trough?

Tutor. With these, a variety of experiments may be made upon combustible bodies. I will show you one with gunpowder, but I must have recourse to four troughs, united by cramps, or to one much larger than this.

Towards the ends of the wires are two

pieces of glass tubes, these are for the operator to hold by, while he directs the wires. Suppose now four or more troughs united, and the wire to be at the two extremities, I put some gun-powder on a piece of flat glass, and then holding the wires by the glass tubes, I bring the ends of them to the gunpowder, and just before they touch, the gunpowder will be inflamed.

Instead of gunpowder, gold and silver leaf may be burnt in this way: ether, spirits of wine, and other inflammable substances, are easily fired by the Voltaic battery; it will consume even small metallic wires.

Copper or brass leaf, commonly called Dutch gold, burns with a beautiful greer light, silver with a pale blue light, and golc with a yellowish green light.

James. Will the battery continue to ac any great length of time?

Tutor. The action of all these kind c batteries is the strongest, when they are firs filled with the fluid; and it declines in pro portion as the metals are oxidated, or th fluid loses its power. Of course, after

certain time, the fluid must be changed and the metals cleaned, either with sand, or by immersing them a short time in diluted muriatic acid. The best fluid for filling the cells with, is water mixed with one-tenth of nitreous acid. Care must always be taken to wipe quite dry the edges of the plates, to prevent a communication between the cells: and it will be found, that the energy of the battery is in proportion to the rapidity with which the zinc is oxidated.

CONVERSATION XLVI.

Voltaic Conductors—Circles—Tables—Experiment

TUTOR. You know that *conductors* of the electric fluid differ from each other in their conducting power.

Charles. Yes, the metals were the most perfect conductors, then charcoal, afterwards water and other fluids. See p. 225.

Tutor. In Voltaism we call the former *dry* and *perfect* conductors, these are the first class: the latter, or second class, *imperfect* conductors: and in rendering the Vol-aic power sensible, the combination must onsist of three conductors of the different asses.

James. Do you mean two of the first ss, and one of the second?

Tutor. When two of these bodies are of the first class, and one is of the second, the combination is said to be of the *first order*.

Charles. The large battery which you used yesterday was of the *first order* then, because there were two metals, viz. zinc and silver, and one fluid.

Tutor. This is called a *simple Voltaic circle*, the two metals touched each other in some points, and at other points they were connected by the fluid which was of the different class.

James. Will you give us an example of the second order?

Tutor. When a person drinks porter from a pewter mug, the moisture of his under lip is one conductor of the second class, the porter is the other, and the metal is the third body, or conductor of the first class.

The discoloration of a silver spoon, in the act of eating eggs, is a Voltaic operation. A spoon merely immersed in the egg undergoes no discoloration, it is the act of eating *that produces* the change. This is a Voltaic

combination of the second order, the [illegible] egg, and the saliva, are substances of the second class of conductors, and the silver of the first class.

Charles. Which are the most powerful Voltaic circles?

Tutor. They are those of the first order, where two solids of different degrees of oxidability are combined with a fluid capable of oxidating at least one of the solids. Thus gold, silver, and water, do not form an active Voltaic circle; but it will become active if a little nitric acid, or any fluid decomposible by silver, be mixed with the water. An active Voltaic circle is formed of zinc, silver, and water, because the zinc is oxidated by water. But a little nitric acid, added to the water, renders the combination still more active, as the acid acts upon the silver and the zinc.

The most powerful Voltaic combinations of the second order are, where two conductors of the second class have different chemical actions on the conductors of the first class, at the same time they act upon each

other. Thus copper, silver, or lead, with a solution of an alkaline sulphuret* and diluted nitrous acid, form a very active Voltaic circle. Hence the following

TABLES.

Table of Voltaic circles of the *first order*, composed of two perfect conductors, and one imperfect conductor.

Very Oxidable Substances.	Less Oxidable Substances	Oxidating Fluids.
Zinc - -	With gold charcoal, silver, copper, tin, iron, mercury	Solutions of nitric acid in water, of muriatic acid, and sulphuric acid, &c. Water holding in solution oxygen atmospheric air, &c.
Iron - -	With gold, charcoal, silver, copper, tin	
Tin - -	With gold, silver, charcoal	
Lead - -	With gold, silver	
Copper -	With gold, silver	Solution of nitrate of silver, and mercury, nitric acid, acetous acid.
Silver - -	With gold	Nitric acid.

* If equal quantities of sulphur and alkali be melted in a covered crucible, the mass obtained is called an alkaline sulphuret.

Table of Voltaic circles of the *second order*, composed of two imperfect conductors, and one perfect conductor.

Perfect Conductors.		Imperfect Conductors		Imperfect Conductors.
Charcoal Copper - Silver - Lead - Tin - - Iron - - Zinc - -	}	Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three.	{	Solution of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.

I will now show you another experiment which is to be made with the assistance of the great battery (Fig. 22.) A B (Plate VIII. Fig. 23.) exhibits a glass tube, filled with distilled water, and having a cork at each end. A and B are two pieces of brass wire, which are brought to within an inch or two of one another in the tube, and the other ends are carried to the battery, viz. A to what is called the positive end, and B to the negative end.

James. You have then positive and negative Voltaism, as well as electricity?

Tutor. Yes, and if the circuit be interrupted, the process will not go on. But if all things be as I have just described, you will see a constant stream of bubbles of gas proceed from the wire B, which will ascend to the upper part of the tube. This gas is found to be hydrogen or inflammable air.

Charles. How is that ascertained?

Tutor. By bringing a candle close to the opening when I take out the cork A, the gas will immediately inflame. The bubbles which proceed from the wire A are oxygen or pure air, they accumulate and stick about the sides of the tube.

James. How is this experiment explained?

Tutor. It is believed that the water is decomposed or divided into hydrogen and oxygen: the hydrogen is separated from the water by the wire connected with the negative extremity, while the oxygen unites with and oxidates the wire connected with the positive end of the battery.

If I connect the positive end of the battery with the lower wire, and the negative with the upper, then the hydrogen proceeds

from the upper wire, and the lower
oxidated.

If wires of gold or platina be used
are not oxidable, then a stream of gas
from each, which may be collecte
will be found to be a mixture of hy
and oxygen.

Charles. Are there no means of c
ing these fluids separately:

Tutor. Yes, instead of making
the tube, let the extremities of the
which proceed from the battery, be i
sed in water, at the distance of an inch
each other, then suspend over each
vessel, inverted and full of water
VIII. Fig. 24.) and different kinds
will be found in the two glasses.

It is known that hydrogen gas re
the oxides of metals, that is, restores
to their metallic state. If, therefor
tube (Fig. 23.) be filled with a solut
acetite of lead* in distilled water,
communication is made with the ba
no gas is *perceived* to issue from the

---

*Acetite of lead, is a solution of lead in aceto

which proceeds from the *negative* end of the battery, but in a few minutes, beautiful metallic needles may be seen on the extremity of this wire.

James. Is this the lead separated from the fluid?

Tutor. It is; and you perceive it is in a perfect metallic state, and very brilliant. Let the operation proceed, and these needles will assume the form of fern, or some other vegetable substance.

The spark from a Voltaic* battery acts with wonderful activity upon all inflammable bodies, and experiments made in a dark room, upon gun-powder, charcoal, metallic wire, and metallic leaves, &c. may be made very amusing.

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* Mr. Davy has, by means of a very powerful battery, been enabled to decompose the alkalies, many of the earths, sulphur, phosphorus, and charcoal; also the boracic, fluoric, and muriatic acids. His first experiments were on potash and soda, which instead of being simple substances are found to consists of certain metallic substances and oxygen. See Dialogues on Chemistry.

CONVERSATION XLVII.

Miscellaneous Experiments.

TUTOR. The discoveries of Ga
were made principally with dead fr
from his experiments, and many o
that have been made since his time, i
pears that the *nerves of animals* may b
lected by smaller quantities of electı
than any other substances with whicl
are acquainted. Hence limbs of aniı
properly prepared, have been much em
ed for ascertaining the Voltaic electric

Charles. What is the method of p
ration.

Tutor. I have been cautious in
tioning experiments on animals, lest

should lead you to trifle with their feelings: I must, however, to render the subject more complete, tell you what has been done.

The muscles of a frog lately dead, and skinned, may be brought into action by means of very small quantities of common electricity.

If the leg of a frog recently dead be *prepared*, that is, separated from the rest of the body, having a small portion of the spine attached to it, and so situated that a little electricity may pass through it, the leg will be instantly affected with a kind of spasmodic contraction, sometimes so strong as to jump a considerable distance.

It is now known that similar effects may be produced in the limb thus *prepared*, by only making a communication between the nerves and the muscles, by a conducting substance. Thus, in an animal recently dead, if a nerve be detached from the surrounding parts; and the coverings be removed from over the muscles, which de-

pend on that nerve; and if a piece of metal, as a wire, touch the nerve with one extremity, and the muscle with the other, the limb will be convulsed.

Charles. Is it necessary that the communication between the nerve and the muscle should be made with a conducting substance?

Tutor. Yes, it is: for if sealing-wax, glass, &c. be used, instead of metals, no motion will be produced.

If part of a nerve of a *prepared* limb be wrapped up in a slip of tin foil, or be laid on a piece of zinc, and a piece of silver be laid with one end upon the muscle, and with the other on the tin or zinc, the motion of the limb will be very violent.

Here are two wine-glasses almost full of water, and so near to each other as barely not to touch. I put the *prepared* limb of the frog into one glass, and lay the nerve, which is wrapped up in tin foil, over the edges of the two glasses, so that the tin may touch the water of the glass in which

the limb is not. If I now form a communication between the water in two glasses, by means of silver as a pair of tea-tongs; or put the fingers of one hand into the water of the glass that contains the leg, and hold a piece of silver in the other, so as to touch the coating of the nerves with it, the limb will be immediately excited, and sometimes when the experiment is well made, the leg will even jump out of the glass.

James. It is very surprising that such kind of motions should be produced in dead animals.

Tutor. They may be excited also in living ones: if a live frog be placed on a plate of zinc, having a slip of tin foil upon its back, and a communication be made between the zinc and tin foil, by a piece of metal, as silver, the same kind of contractions will take place.

Charles. Can this experiment be made without injury to the animal?

Tutor. Yes, and so may the following.

—I take a live flounder and dry it with a cloth, and then put it in a pewter plate, or upon a large piece of tin foil, and place a piece of silver on its back: I now make a communication between the metals with any conducting substance, and you see the contractions, and the fish's uneasiness. The fish may now be replaced in water.

I place this leech on a crown piece, and then, in its endeavour to move away, let it touch a piece of zinc with its mouth, and you will see it instantly recoil, as if in great pain: the same thing may be done with a worm.

It is believed that all animals, whether small or great, may be affected, in some such manner, by Voltaism though in different degrees.

The limbs of people, while undergoing the operation of amputation, have been convulsed by the application of the instruments, an effect which is easily explained by Voltaism.

By the knowledge already obtained in

this science, the following facts are readily explained.

Pure mercury retains its metallic splendour during a long time; but its amalgam with any other metal is soon tarnished or oxidated.

Ancient inscriptions, engraved upon pure lead, are preserved to this day, whereas some metals composed of lead and tin of no great antiquity, are very much corroded.

Works of metals, whose parts are soldered together by the interposition of other metals, soon oxidate about the parts where the different metals are joined. And there are persons who profess to find out seams in brass and copper vessels by the tongue, which the eye cannot discover; and they can, by this means, distinguish the base mixtures which abound in gold and silver trinkets.

When the copper sheeting of ships is fastened on by means of iron nails, those nails, but particularly the copper, are very *quickly* corroded about the place of contact.

A piece of zinc may be kept in water a long time, without scarcely oxidating at all; but the oxidation takes place very soon if a piece of silver touch the zinc, while standing in the water.

If a cup made of zinc or tin be filled with water, and placed upon a silver waiter, and the tip of the tongue be applied to the water, it is found to be insipid; but if the waiter be held in the hand, which is well moistened with water, and the tongue applied as before, an acid taste will be perceived.

Charles. Is that owing to the circuit being made complete by the wet hand?

Tutor. It is: another experiment of a similar kind as the following: If a tin bason be filled with soap-suds, lime-water, or a strong ley, and then the bason be held in both hands, moistened with pure water, while the tongue is applied to the fluid in the bason, an *acid* taste will be sensibly perceived, though the liquor is *alkaline*.

From this short account of Voltaism, it may be inferred :—

(1.) That it appears to be only another mode of exciting electricity.

(2.) Voltaic electricity is produced by the chemical action of bodies upon each other.

(3.) The oxidation of metals appears to produce it in great quantities.

(4.) Voltaic electricity can be made to set inflammable substances on fire, to oxidate and even inflame metals.

(5.) The nerves of animals appear to be most easily affected by it of any known substances.

(6.) Voltaic electricity is conducted by the same substances as common electricity.

(7.) When it is made to pass through an animal, it produces a sensation resembling the electrical shock.

(8.) The electricity produced by the torpedo and electrical eel, is very similar to Voltaism.

INDEX AND GLOSSARY.

TO THE

THREE VOLUMES.

A.

B.

Aurora [illegible]
Ax [illegible]
[illegible]
[illegible]

D.

F.

G.

H.

I.

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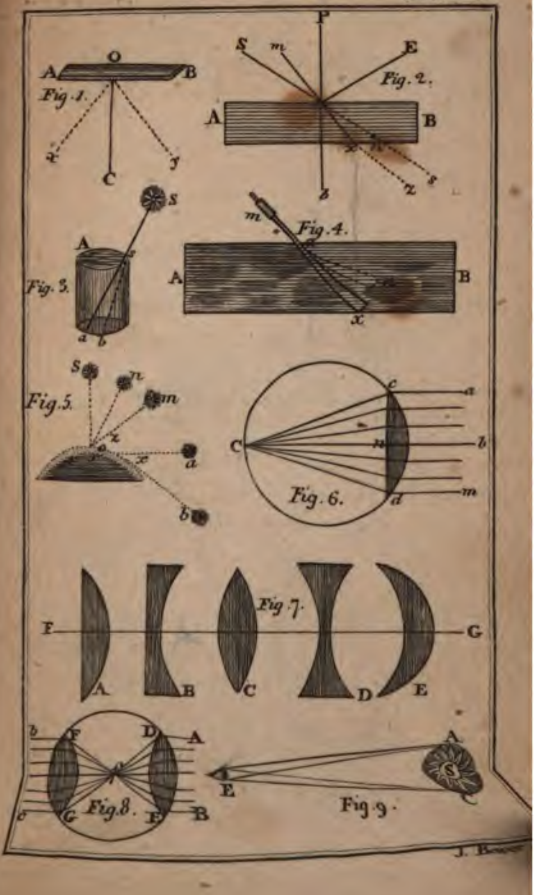

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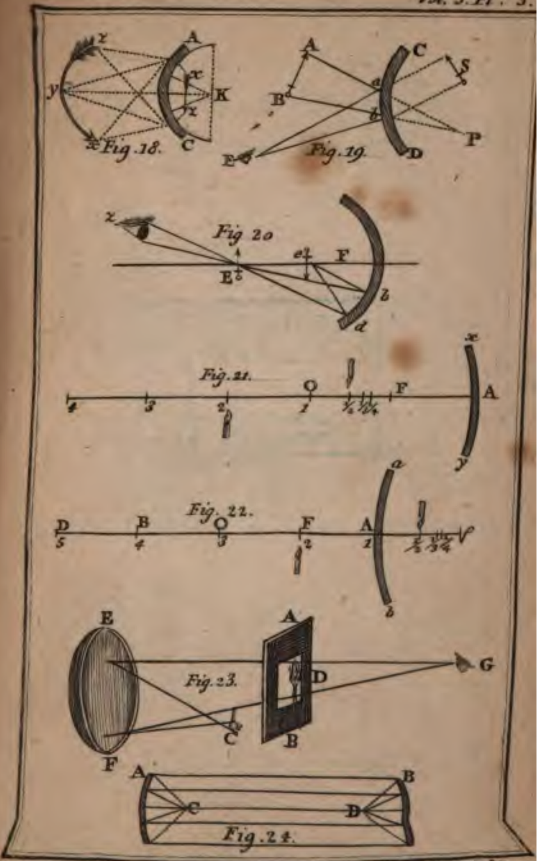

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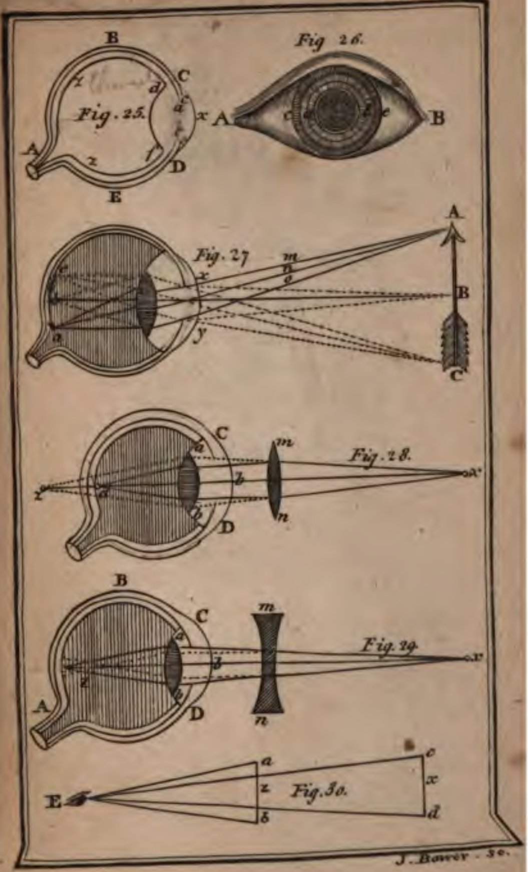

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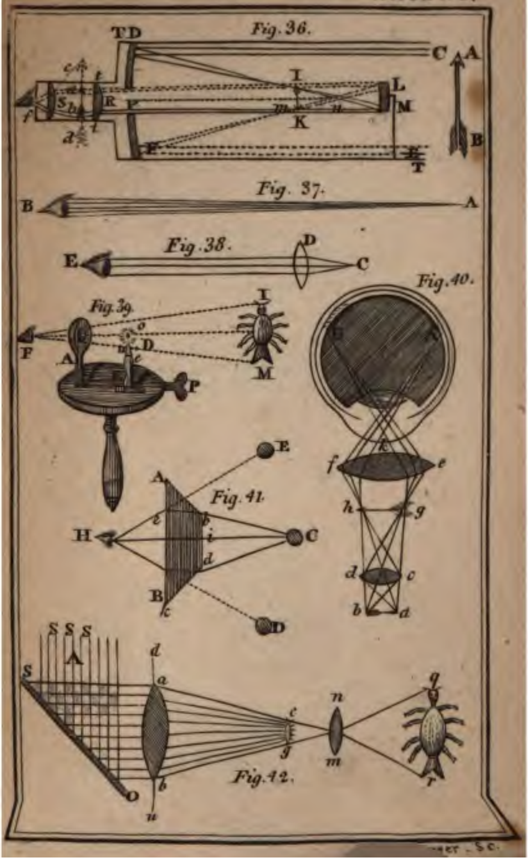
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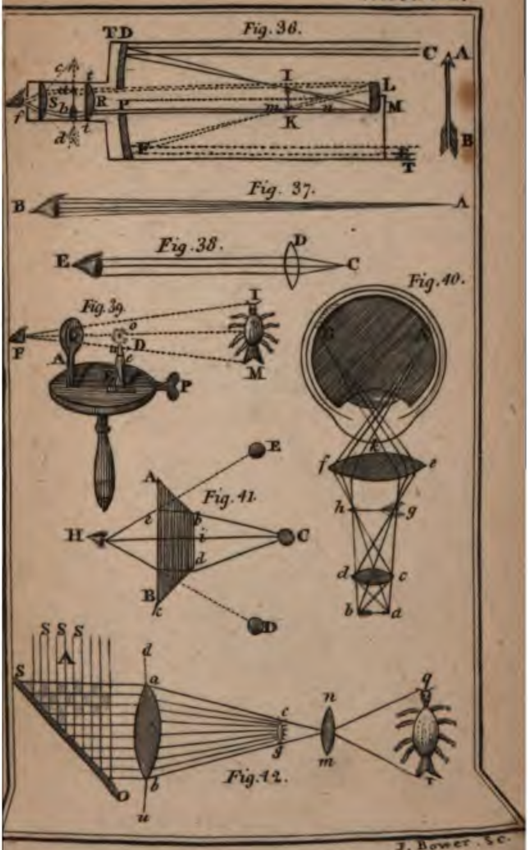

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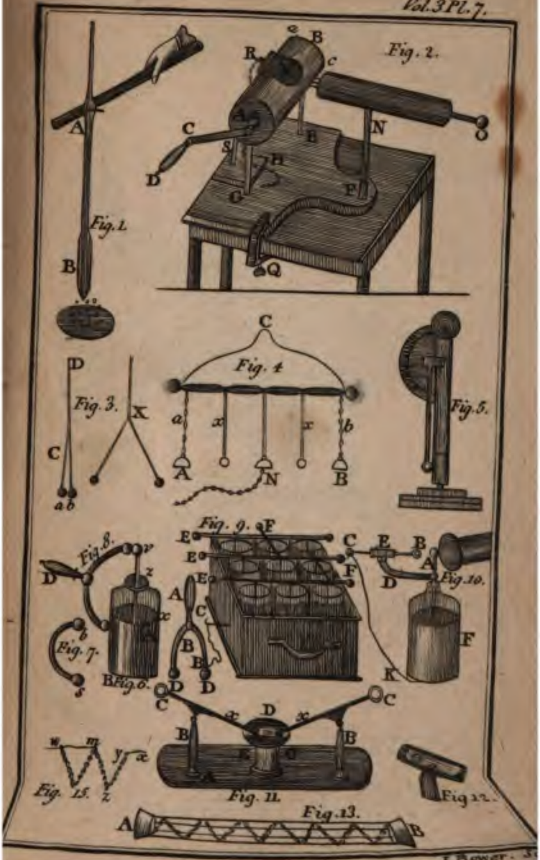
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B
C
D
Fig. 27.

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